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April 1988

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Electronics & Technology Today

Canada's Magazine for High-tech Discovery

Volume 12, Number 4 — April, 1988



The Daetron MM100 was photographed by Bill Markwick; the VCR photo is courtesy of JVC.

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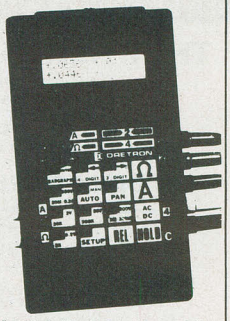
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Daetron MM100 Multimeter

A comprehensive multimeter that can test four voltages at once, plus many other features.

By Bill Markwick

The Daetron MM100 4-in-1 multimeter follows on the success of the MC300 Capacitance Meter, using microprocessor control as well to give a multitude of features, including multiplexed scanning of four input channels into the same A-to-D converter. The flexibility of use makes it ideal for troubleshooting, educational use, quality control or the laboratory.

Basics

When first switched on, the MM100 shows two lines of 16 characters on its LCD display; the default display is four voltage measurements using seven characters each in the 3 1/2 digit mode. The autoranging goes from 0.2V to 500V on DC volts for full-scale, with a basic accuracy of 0.1% with an input impedance of 10 megohms.

AC volts are read on channel 1 only, with ranges of 2, 20, 200 and 500V. Basic accuracy is 2% with an input impedance of 10 megohms. Resistance is read on channel 3 only, from 2k to 20M full scale. DC current is read on channel 1 only, with ranges of 20mA and 200mA.

The displays add a V, v, m or K to the reading to indicate DC volts, AC volts, milliamperes or kilohms, respectively.

The 4" by 7" case has a 16-key membrane keyboard and seven color-coded banana jacks. The unit is powered by a 9V battery or optional AC adapter. The contrast of the LCD display can be altered to suit the viewing angle by adjusting a trim pot in the battery compartment.

The MM100 is made in Canada and costs $189.95 with a manual and a pair of test leads. Optional equipment includes a case, extra leads, and an AC adapter.

Tryout

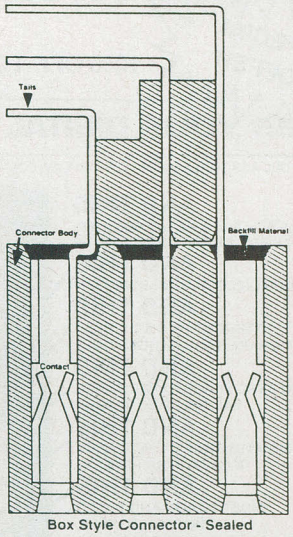
The first thing you'll notice in using the MM100 is that a 4- channel meter just naturally creates a tangle of cords. For this reason, it's well worth investing $39.95 in the optional 6-lead color-coded set, available with either EZ hooks or alligator clip termination.

When the unit is powered up, only channel 1 is programmed to respond to commands like Hold or manual ranging; we'll get back to the programming mode shortly; here's a quick tour of the keyboard. Pressing the Hold key brings up a tiny "H" on the display of channels that are programmed for this feature, and the display locks at whatever value was displayed at the time. A second press deselects the Hold feature.

The Rel key switches the channel(s) from regular voltage measurement to the Relative mode; whatever voltage is on the display when the key is pressed is taken as the new zero volts and subtracted from the reading (which will now be zero). For example, you could have one of the channels monitoring the output of a power supply while the others do regular measurements; the power supply channel in the Relative mode will display only the changes, not the supply voltage itself. The plus and minus signs indicate whether the change has been an increase or decrease.

The Relative function is also useful for zeroing the meter if there's a lot of constant noise in the circuit.

The AC/DC key toggles channel 1 only; there's only one internal rectifier. The Auto/Man key lets you manually set the range on preselected channels.



Box Style Connector - Sealed



Transistor Tester

An in-circuit transistor tester that will test your components rather than your patience.

By Allan Wilcox

How many hours have you spent testing transistor after transistor in a ponderous search for the monstrous component that has blackened your goldenPCB? How often do you wish for a device that could tell good from bad with a single prod from a probe?

Wish no longer. This tester will confirm a single measurement if a diode, transistor or thyristor is OK as well as showing its polarity (PNP/NPN for a transistor and PN/NP for a diode). It is tolerant of in-circuit resistance of the order of 40R across the junctions so you can flit from component to component without once reaching for your soldering iron. There is even a buzzer which sounds whenever a healthy piece of semiconductor is tested.

The Test

To test a transistor a 5Hz square wave is applied to the collector-emitter terminals of the device being examined (see Fig.1). Forward bias is supplied to the base, again with a 5Hz square wave.

The low saturation voltage of a good transistor is taken as the indication of a good device but is differentiated from a short circuit by checking that conduction occurs in one direction only.

If conduction occurs on the positive half-cycle (relative to the emitter) this is interpreted as being a good NPN transistor.

Conduction on the other half-cycle would be due to a good PNP device.

The design criterion here is that the collector-emitter voltage must fall below 500mV for a good indication to be given. This ensures the tester ignores any diodes that may be in circuit. This is particularly important in order to detect a collector- base short which would act as a diode, conducting on one half- cycle only and erroneously indicating a good device.

Diodes, thyristors and Darlington transistors have a forward voltage drop between 500mV and 1V so to test these a separate range is provided. On this range the threshold for a good indication is increased to approximately 1V.

The Display

A 4-digit LCD is used to show the status of the device under test. The first three 'digits' can show either an n or a p, and indicate the device type. The first digit is blanked when testing diodes.

The fourth digit shows either a t or a d to indicate transistor or diode range. It also serves as an 'on' indicator. Failed devices will give a display of nnn on the LCD if the test terminals are short circuited. If they are open circuit, the first three letters of the LCD are blank.

Construction

The component overlay for the main PCB is shown in Fig 2. All ICs are CMOS and so the usual precautions against static should be taken. Note that they all face the same way on the board.

All odd numbered transistors are PNP and even numbered are NPN. The presets RV1, RV2 may be replaced by 4M7 fixed resistors with just a small increase in the response time resulting.

Avoid any stress on the LCD display, taking care not to overtighten any fixing nuts. The mounting bezel specified comes complete with two socket strips on a board. These were removed and used on the display PCB (fig.3). Take care to observe the polarity of the ribbon cable when connecting the main PCB to the display PCB.

Note that the two switches are momentary push to make, similar to a keyboard type. The ones used on the prototype were from the junk box.

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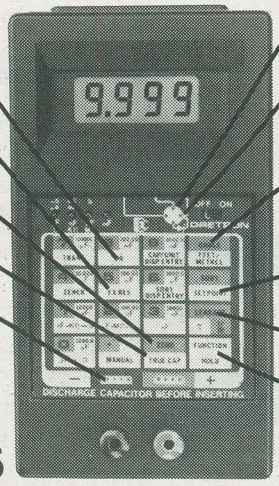
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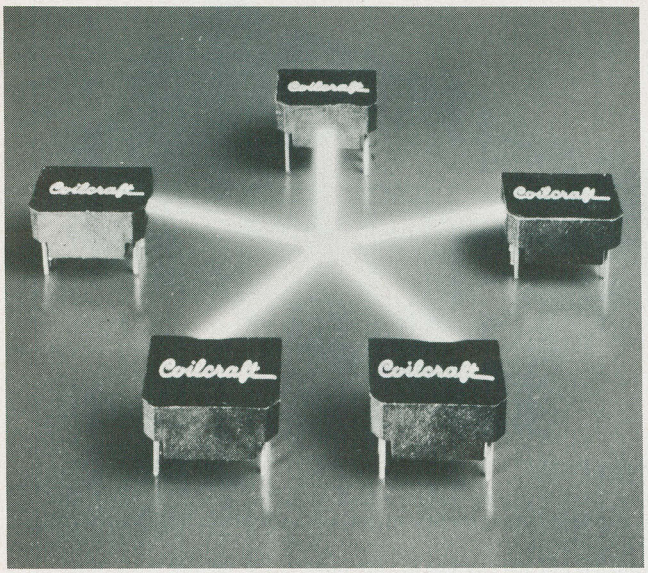
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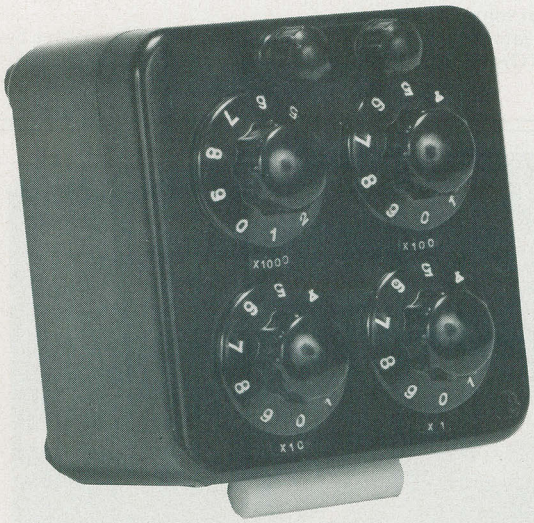
Anyone involved in designing local area network equipment might be interested in a new low cost, off-the-shelf LAN transformer.

Coilcraft's LAX-ST100 transformer interfaces both node and hub driver circuitry to the twisted pair wiring and provides impedance matching, 2000 volt isolation, and 60 dB common mode rejection.

The device measures only 0.35" x 0.50" and is suitable for use in LANs described by the IEEE 802.3 standard.

For more information about the LAX-ST100 contact: Paul Liebman, Coilcraft, 1102 Silver Lake Road, Cary IL 60013. (312) 639-6400.

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Precision Resistance Box

Selecting any resistance value from 1 ohm to 9999 ohms is easy with the Brunelle Model 63 Precision Resistance Decade Box.

It's suitable for use in electrical measurements, as a substitution resistor to aid in designing and for experimentation in schools and research institutes. Resistors are formed with manganin wire wound elements and the unit has low zero resistance and low inductance.

For more information on the Precision Resistance Box contact: Brunelle Instruments Inc., 73 - 6th Range S., St. Elie D'Orford, Quebec J0B 2S0. Ph: (819) 563-9096.

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In-Circuit Emulator

A new in-circuit emulator that will allow development support for a full range of CPUs, 8 to 32 bits, with simple module exchanges is available

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Contact John Arata, Ziltek Corporation, 1651 East Edinger Ave., Santa Ana, California 92705-5001.

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A GPIB product from Britain is available for use as a IEEE-488 bus expander and a cost effective RS-232 to IEEE-488 converter.

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For more information on the Model 2010 contact: Matt Duncan, Duncan Instruments Ltd., 121 Milvan Drive, Weston, Ontario M9L 1Z8. Ph: (416) 742-4448 or FAX (416) 749-5053.

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Amoco Laser Address

In our October 1987 issue we featured an article on semiconductor lasers in which products from the Amoco Laser Co. were mentioned. However, we failed to give the address for Amoco, so here it is: Amoco Laser, 1809 Mill Street, Naperville, Illinois 60540 (312) 369-4190

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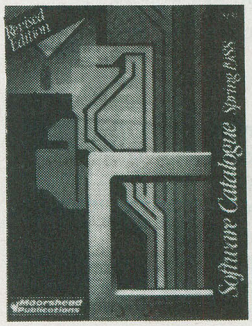
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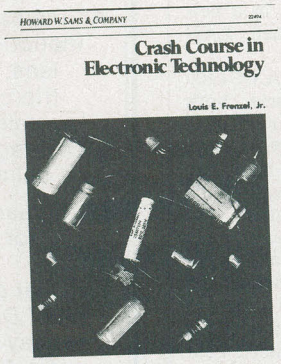


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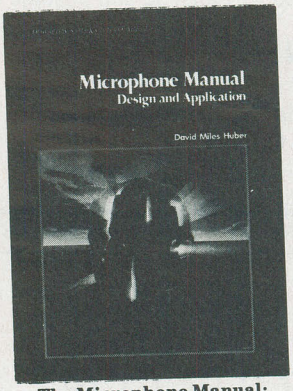
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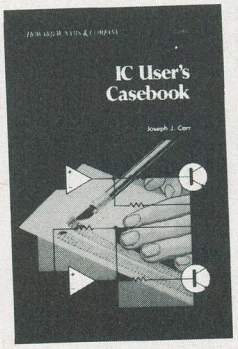
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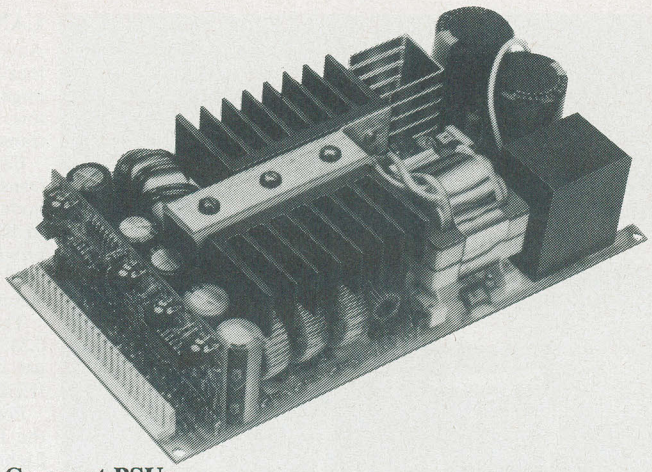
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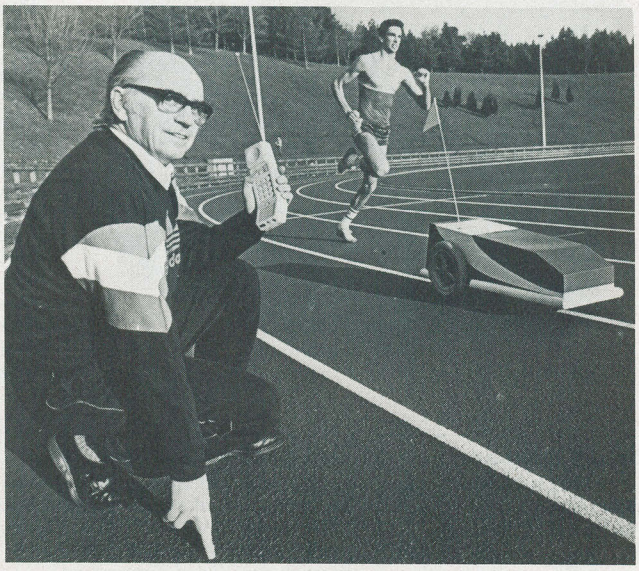
Compact PSUs

Two new models of convection cooled switching power supplies with several standard output configurations are available in a compact 4.25" and 8.50" footprint.

The models PSI 135 and PSI 225 are rated at 135 and 225 watts respectively. There are over 20 options available for customizing the units including up to four fully regulated outputs, L-brackets for special mounting, and input voltage autoranging.

For more information contact: Richard Milne, PSI/STD, Power Systems Inc., 45 Griffin Road South, Bloomfield, CT 06002 (203) 726-1300.

Circle No. 74 on Reader Service Card



Experimental Mechanical Pacer

The athlete pace-maker who runs every circuit of the track with tireless efficiency whenever needed has not yet been born. But for serious athletes wishing to improve their stamina, speed and pace judgement engineers in Northern Ireland have designed a mechanical pacer.

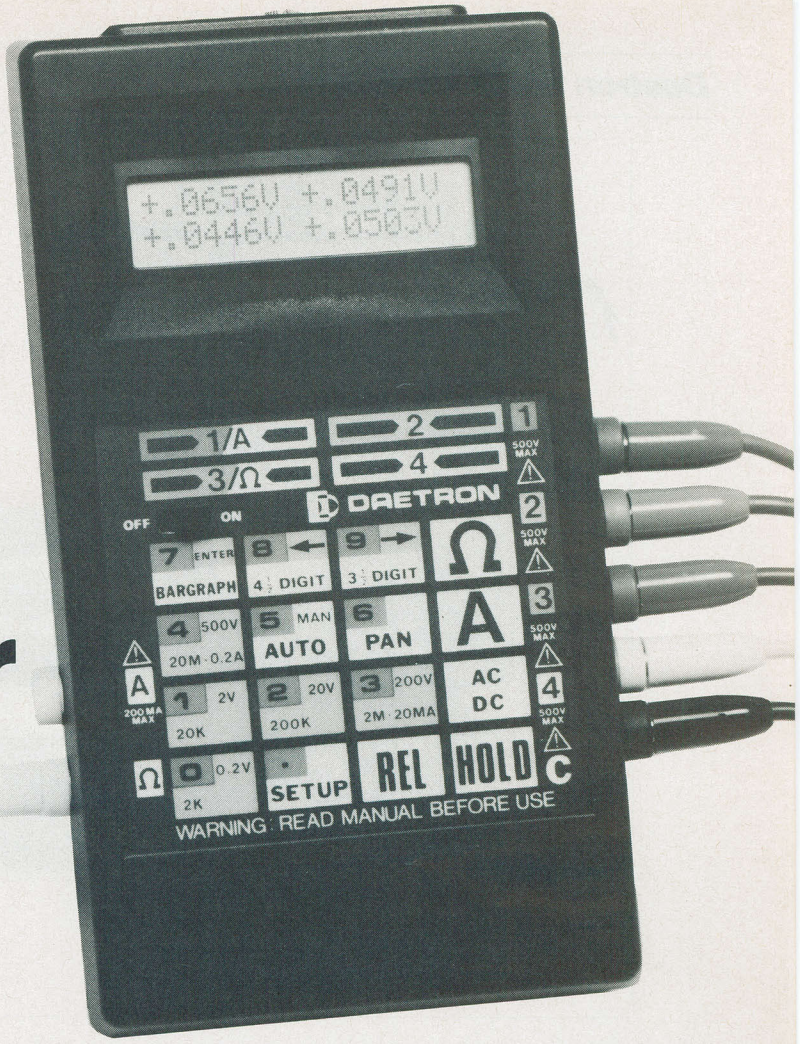
Resembling a child's pedal car, the 0.9m-long, three- wheeled remotely guided vehicle is designed to alongside, or ahead of, an athlete and can cover 400m in 40 seconds - faster than any human.

The pace car has a guidance mechanism with light activated sensors that follow a pre-selected single white line, such as a track lane marker. The speed is set by the runner or his/her coach through digital codes keyed into an on-board computer by portable telephone. The telephone also assists communication between coach and athlete when the runner is out of earshot. Once a lap has been completed, the pacer can be made to repeat its performance exactly or be adjusted to meet requirements.

For more information contact: Tom Keating or William Beattie, Queens University of Belfast, University Rd., Belfast BT7 1NN Northern Ireland.

Continued on page 21.

Daetron MM100 Multimeter



A comprehensive multimeter that can test four voltages at once, plus many other features.

By Bill Markwick

The Daetron MM100 4-in-1 multimeter follows on the success of the MC300 Capacitance Meter, using microprocessor control as well to give a multitude of features, including multiplexed scanning of four input channels into the same A-to-D converter. The flexibility of use makes it ideal for troubleshooting, educational use, quality control or the laboratory.

Basics

When first switched on, the MM100 shows two lines of 16 characters on its LCD display; the default display is four voltage measurements using seven characters each in the 3 1/2 digit mode. The autoranging goes from 0.2V to 500V on DC volts for full scale, with a basic accuracy of 0.1% with an input impedance of 10 megohms.

AC volts are read on channel 1 only, with ranges of 2, 20, 200 and 500V. Basic accuracy is 2% with an input impedance of 10 megohms. Resistance is read on channel 3 only, from 2k to 20M full scale. DC current is read on channel 1 only, with ranges of 20mA and 200mA.

The displays add a V, v, m or K to the reading to indicate DC volts, AC volts, milliamperes or kilohms, respectively.

The 4" by 7" case has a 16-key membrane keyboard and seven color-coded banana jacks. The unit is powered by a 9V battery or optional AC adapter. The contrast of the LCD display can be altered to suit the viewing angle by adjusting a trim pot in the battery compartment.

The MM100 is made in Canada and costs $189.95 with a manual and a pair of test leads. Optional equipment includes a case, extra leads, and an AC adapter.

Tryout

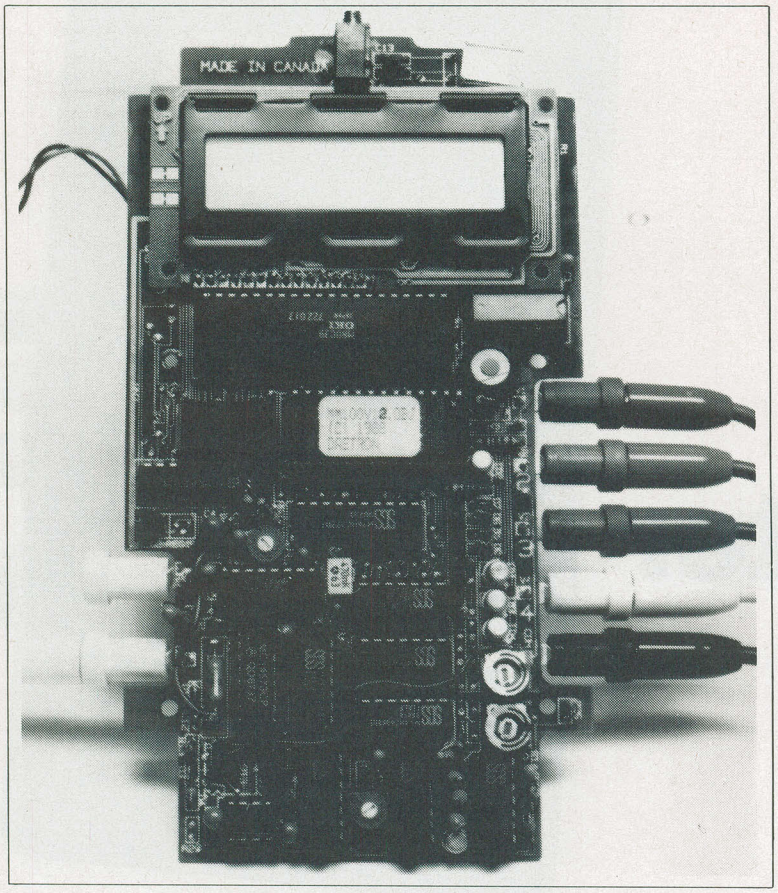
The first thing you'll notice in using the MM100 is that a 4- channel meter just naturally creates a tangle of cords. For this reason, it's well worth investing $39.95 in the optional 6-lead color-coded set, available with either EZ hooks or alligator clip termination.

When the unit is powered up, only channel 1 is programmed to respond to commands like Hold or manual ranging; we'll get back to the programming mode shortly; here's a quick tour of the keyboard. Pressing the Hold key brings up a tiny "H" on the display of channels that are programmed for this feature, and the display locks at whatever value was displayed at the time. A second press deselects the Hold feature.

The Rel key switches the channel(s) from regular voltage measurement to the Relative mode; whatever voltage is on the display when the key is pressed is taken as the new zero volts and subtracted from the reading (which will now be zero). For example, you could have one of the channels monitoring the output of a power supply while the others do regular measurements; the power supply channel in the Relative mode will display only the changes, not the supply voltage itself. The plus and minus signs indicate whether the change has been an increase or decrease.

The Relative function is also useful for zeroing the meter if there's a lot of constant noise in the circuit.

The AC/DC key toggles channel 1 only; there's only one internal rectifier. The Auto/Man key lets you manually set the range on preselected channels.



The MM100 is built on a single printed circuit card, using standard CMOS switches, a commercial CPU and a custom ROM chip.

The Pan key switches channel 1 to a display that looks like 000.000.000; these groups represent volts, millivolts and microvolts. If you need more resolution than the necessarily small 4-channel display, the Pan feature gives you 9-digit performance.

The 4 1/2 digit key is a compromise between 4-channel and the 9-digit Pan; it gives you two channels (1 and 3) with four decimal places each.

The Bargraph switches the display to channel 1 only, with a 4 1/2 digit readout and a 16-segment analog bargraph underneath. If you've ever tried to adjust a circuit in which the voltage levels are constantly changing, you know that a digital readout is very difficult (or impossible) to decipher. The bargraph lets you see graphically what's happening to the level, simplifying the adjustment of tuned circuits or any device where the output changes are not slow and stable.

The current and resistance features have their own jacks on the left side. Channel 1 is for milliamps and channel 3 is for ohms; the separate leads eliminate unplugging your setup if you want to measure these parameters. A 250mA fuse (with a spare) is located in the battery compartment.

The Setup Menu

Pressing Setup displays "mchr" in each channel's place. This stands for Manual, Comparative, Hold and Relative; the lower case letter indicates that the feature is not selected yet, and upper case indicates that the feature will now be toggled by the appropriate control key. For instance, you could have channels 1 and 2 held when you press the Hold key, or channels 2 and 3 toggled in and out of the Relative mode, or various other combinations.

The features are selected and deselected by cursoring over to the letter and pressing Enter (the 7, 8 and 9 keys do double duty for this in the Setup mode).

The ability to set each channel's characteristics individually increases the meter's versatility considerably. You could have the meter monitoring a breadboard setup, with some channels measuring absolute voltages and some measuring only changes at certain test points. Some channels could be put on Hold for later comparison.

The Comparative Mode

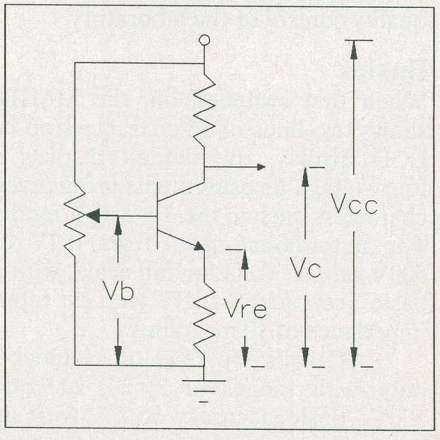
If you'd like to be notified that a quantity has fallen, risen, or passed through specified limits, you can set any of the four channels into the comparative mode from the Setup menu. When the comparative mode is activated, right and left arrows appear; you then enter the greater-than and/or less-than values for that particular channel.

If the measured volts, milliamps or ohms exceed the limits that you've entered, the meter's internal beeper will sound rapidly. The comparative feature will save you from having to watch a circuit closely when you think that changes might be happening; the audio signal frees you to do something else.

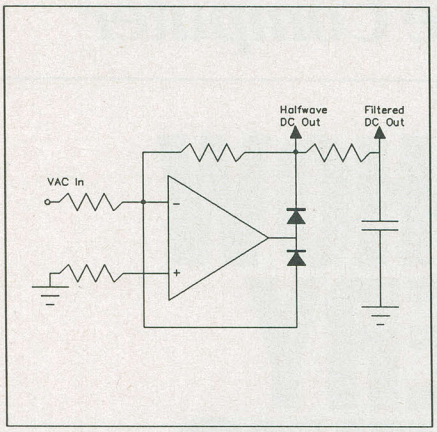
The lower of the two setpoints can be changed without going through the setup menu by pressing the Rel key; the reading on the display at the time becomes the lower setpoint.

Continuity

The usual resistance meter plus continuity beeper has been expanded in the MM100. From the Setup menu, you can specify upper and lower setpoints for the resistance range that appears on channel 3. The beeper will pulse whenever the resistance tested lies between these values, a good fea-



The MM100 would be ideal in educational applications for simultaneously watching the effects of changing transistor biasing, as in the above example.



The ability to watch both AC and DC

because you often want to know if you have a path with a suitably low resistance.

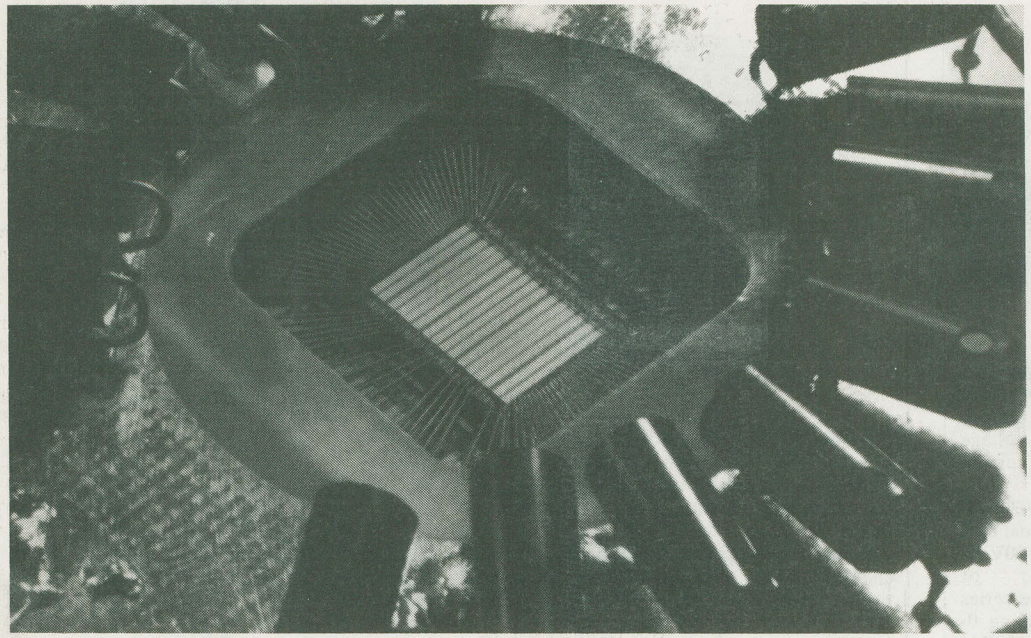
Impressions

The meter is very well made and performed as promised. The scanning and updating isn't the fastest, but it gives a very stable display, without digits toggling and flickering. Watching four readouts at once is a bit confusing at first, but you soon get onto it, and the pleasure of not having to juggle and swap the test leads is a big one.

Any negative points are small ones. I've never been a fan of membrane keyboards because the operation is so

educational uses: I can't think of a better way to demonstrate transistor or op amp biasing than to hook up a 4-channel meter and watch the effect of changing something. Troubleshooting would be simplified, especially if you have to make a lot of interdependent voltage measurements; the Relative, Hold and Comparator functions should let you keep track of those fleeting glitches and their resulting changes. Production lines which have to do several adjust-on-test alignments could do it all without having to move a meter around.

Daetron meters are now being exported to the Far East, certainly



World's Fastest Chip

IBM researchers recently announced that they have what is believed to be the world's fastest DRAM chips. These experimental IBM chips can retrieve a unit of information (bit) in just 20 billionths of a second - three times faster than the current generation of advanced DRAMs.

The advanced design directs power on the chip more precisely, supplies faster circuits at critical points in the chip's access paths and provides more sensitive circuits to detect and amplify the almost infinitesimal signals on the chip to useful levels.

IBM RISC Processor

IBM is also doing research into Reduced Instruction Set Computer (RISC) microprocessors which are said to increase both the speed of memory and logic while decreasing the physical dimensions of the chips.

One such experimental RISC chip, called a fixed-point processor, ran 60 per cent faster than the same chip in a conventional form.

RISC is a concept invented by IBM Fellow John Cocke in 1975 and is applied today in the microprocessor engine of the IBM RT PC engineering workstation as well as in other IBM processors. The RISC concept has also been adopted by the computer industry as the basic blueprint for a number of advanced microprocessors.

Anti Noise Car Stereos

From Britain we bring you this little piece on car stereos that stifle engine boom as they play music.

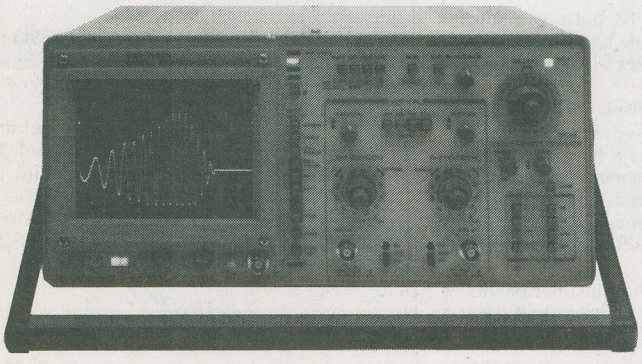
Engine boom is a problem in most modern cars and happens when the engine vibrates at the same frequency as body panels, seats or even the air inside the vehicle. It's usually the loudest when cruising at engine speeds of around 4,000 RPM.

Lotus, a British engineering company, believes that its adaptive noise control system, which instantly responds to engine boom by generating sound of equal amplitude but opposite phase, could be incorporated into conventional car stereos.

The system has been perfected over the past 18 months as a result of collaboration between Lotus and Southampton University scientists.

The recently demonstrated Lotus system used a computer to simulate the engine boom, and four microphones with two 80W loudspeakers to suppress it. A Lotus spokesperson says the amplifier and speakers of car stereos installed in many cars are good enough to support the anti-noise system, so only the inexpensive microphones and a small computer need be added.

If you'd like more information on the anti-noise car stereo system, contact: Lotus Group, Norwich, Norfolk, England NR14 8EZ. Ph: +44-953 608000 or FAX +44-953 606884.



New Intron Scope

The Intron DSO-2020A features 20M samples per second as well as 20 MHz real-time bandwidth. The DSO-2020A also has an 8-bit by 2K memory per channel, X-Y storage and X-Y(t) plot output.

For more information contact RCC Electronics Ltd., 310 Judson Street, Unit 19, Toronto, Ontario M8Z 5T6. Ph: (416) 252- 5094 or FAX (416) 252-3031.

Circle No. 73 on Reader Service Card

Computers and Roses

At the University of Guelph, roses will soon be programming computers. Researchers in horticultural science who listened to plants to determine their need for water no plan to let these plants regulate their own greenhouse environment through an automated computer control system.

"Plants are the ultimate environmental sensors," says horticultural science professor Michael Dixon. They can tell us what their needs are in terms of light, temperature, humidity and soil moisture.

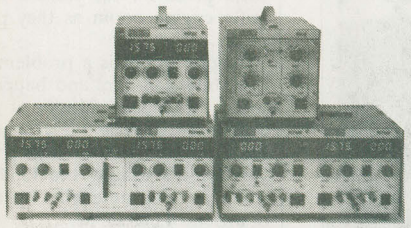
The current project will investigate the effectiveness of a computer-automated control system that responds to changes in a plant's water status. One result of this research will be the development of a set of minimums and maximums, reliable parameters that will enable growers to make better use of sophisticated computer equipment.

"The greenhouse industry's rapid adoption of computer technologies has created a management dilemma," Dixon says. "While an automated greenhouse can maintain an environment, the grower may not know the optimal settings for variables such as temperature, humidity and light intensity. Unfortunately, the development of sensor technologies has lagged behind control hardware and software," he added.

Dixon hopes to change that situation by improving sensor technology and evaluating the problems and advantages of computer-automated greenhouse environments. The department has received much assistance from North American rose growers, and more than $270,000 from the Ontario Ministry of Agriculture and Food will provide the necessary technical expertise needed to operate the program throughout its three-year duration.

It is the ultimate objective of the project to evaluate the plant's response to the whoe environment and then use that response to trigger the automated system that controls the environment.

For Your Information

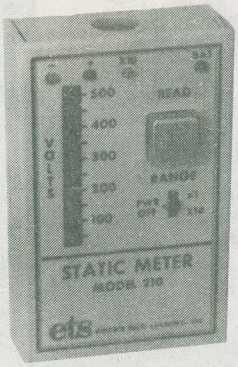


Precision PSUs

The PS732 series from O.K. Industries feature dual 3 3/4 digit display for simultaneous metering of current and voltage. Output controls provide 0.1% accuracy for voltage readings and 0.3% accuracy for current readings.

The PS732 has a single output of 0-30V/0-2A while the PS732-Q features a dual output/quad mode which includes: 2 x 0- 30V /0-2A; 0-30V/0-4A; 0-60V/0-2A; or 0 ± 30V/2A. The third model in the series has three output capabilities including 0-30V/0-2A; 0-30V/0-1A; and ± 5V/7A. Prices start as low as $345US and more information is available from O.K. Electronics Division of O.K. Industries Inc., 4 Executive Plaza, Yonkers, NY 10701.

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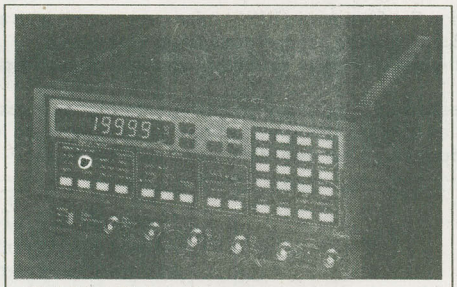
Electrostatic Field Meter

This compact, lightweight meter utilizes a four color array of twelve solid state LEDs to indicate the magnitude and polarity of electrostatic fields.

It features a single range selector switch that enables the user to select either a 0 to ±500 volt range or a 0 to ±5KV range. A yellow X10 indicator illuminates when the 0 to ±5KV range is selected to remind the user to multiply all readings by 10. Polarity indication will automatcally switch whenever the field polarity changes.

For more information contact: Sharon Sandy, electro-tech systems inc., 115 E. Glenside Ave., Glenside, PA 19038.

Circle No. 80 on Reader Service Card



50 MHz Pulse Generator

The Tabor 8500 is a GPIB pulse generator which is fully programmable and is capable of generating high power pulses with rise times of less than 5nS.

Using a 7 digit LED display the 8500 can operate within a period range of 20nS to 2S. At a slightly reduced amplitude level this range can be extended to 14nS (above 70 MHz)

Also featured are a burst generator function, reciprocal counter/time, and storage for up to 30 pre-programmed set up states in non-volatile memory.

Contact Bruce Petty, Duncan Instruments, 121 Milvan Drive, Toronto, Ontario M9L 1Z8.

Circle No. 81 on Reader Service Card

Assistant Editor Moves On

Edward Zapletal, Assistant Editor of Electronics & Technology Today is moving on to become Editor of a new Moorshead Publication titled - Business Computer News. Mr. Zapletal began with Electronics Today as Editorial Assitant in May of 1984 and later became Assistant Editor in September of 1985.

Business Computer News will publish its first bi-weekly issue on April 15th, 1988.

Continued on page 46.

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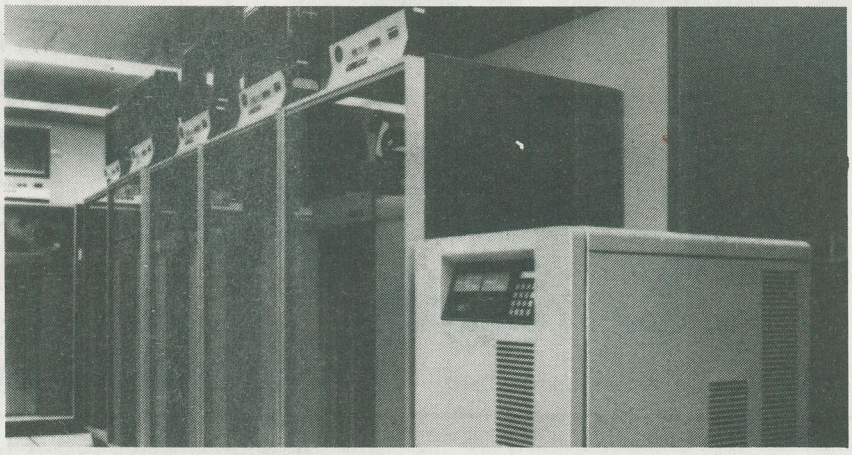
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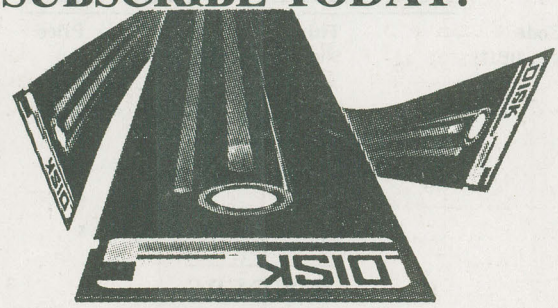
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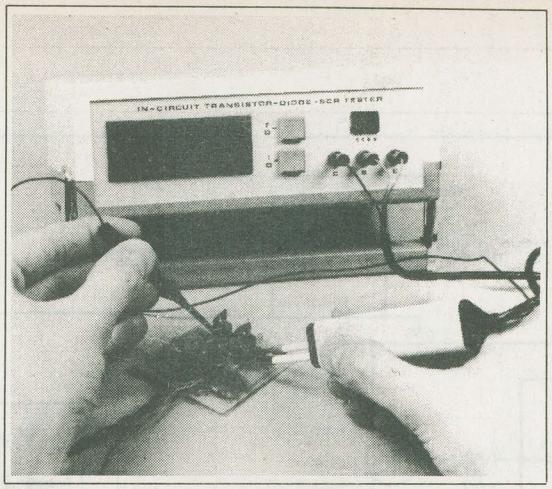
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Transistor Tester

An in-circuit transistor tester that will test your components rather than your patience.

By Allan Wilcox

How many hours have you spent testing transistor after transistor in a ponderous search for the monstrous component that has blackened your golden PCB? How often do you wish for a device that could tell good from bad with a single prod from a probe?

Wish no longer. This tester will confirm a single measurement if a diode, transistor or thyristor is OK as well as showing its polarity (PNP/NPN for a transistor and PN/NP for a diode). It is tolerant of in-circuit resistance of the order of 40R across the junctions so you can flit from component to component without once reaching for your soldering iron. There is even a buzzer which sounds whenever a healthy piece of semiconductor is tested.

The Test

To test a transistor a 5Hz square wave is applied to the collector-emitter terminals of the device being examined (see Fig.1). Forward bias is supplied to the base, again with a 5Hz square wave.

The low saturation voltage of a good transistor is taken as the indication of a good device but is differentiated from a short circuit by checking that conduction occurs in one direction only.

If conduction occurs on the positive half-cycle (relative to the emitter) this is interpreted as being a good NPN transistor.

Conduction on the other half-cycle would be due to a good PNP device.

The design criterion here is that the collector-emitter voltage must fall below 500mV for a good indication to be given. This ensures the tester ignores any diodes that may be in circuit. This is particularly important in order to detect a collector- base short which would act as a diode, conducting on one half- cycle only and erroneously indicating a good device.

Diodes, thyristors and Darlington transistors have a forward voltage drop between 500mV and 1V so to test these a separate range is provided. On this range the threshold for a good indication is increased to approximately 1V.

The Display

A 4-digit LCD is used to show the status of the device under test. The first three 'digits' can show either an n or a p, and indicate the device type. The first digit is blanked when testing diodes.

The fourth digit shows either a t or a d to indicate transistor or diode range. It also serves as an 'on' indicator. Failed devices will give a display of nnn on the LCD if the test terminals are short circuited. If they are open circuit, the first three letters of the LCD are blank.

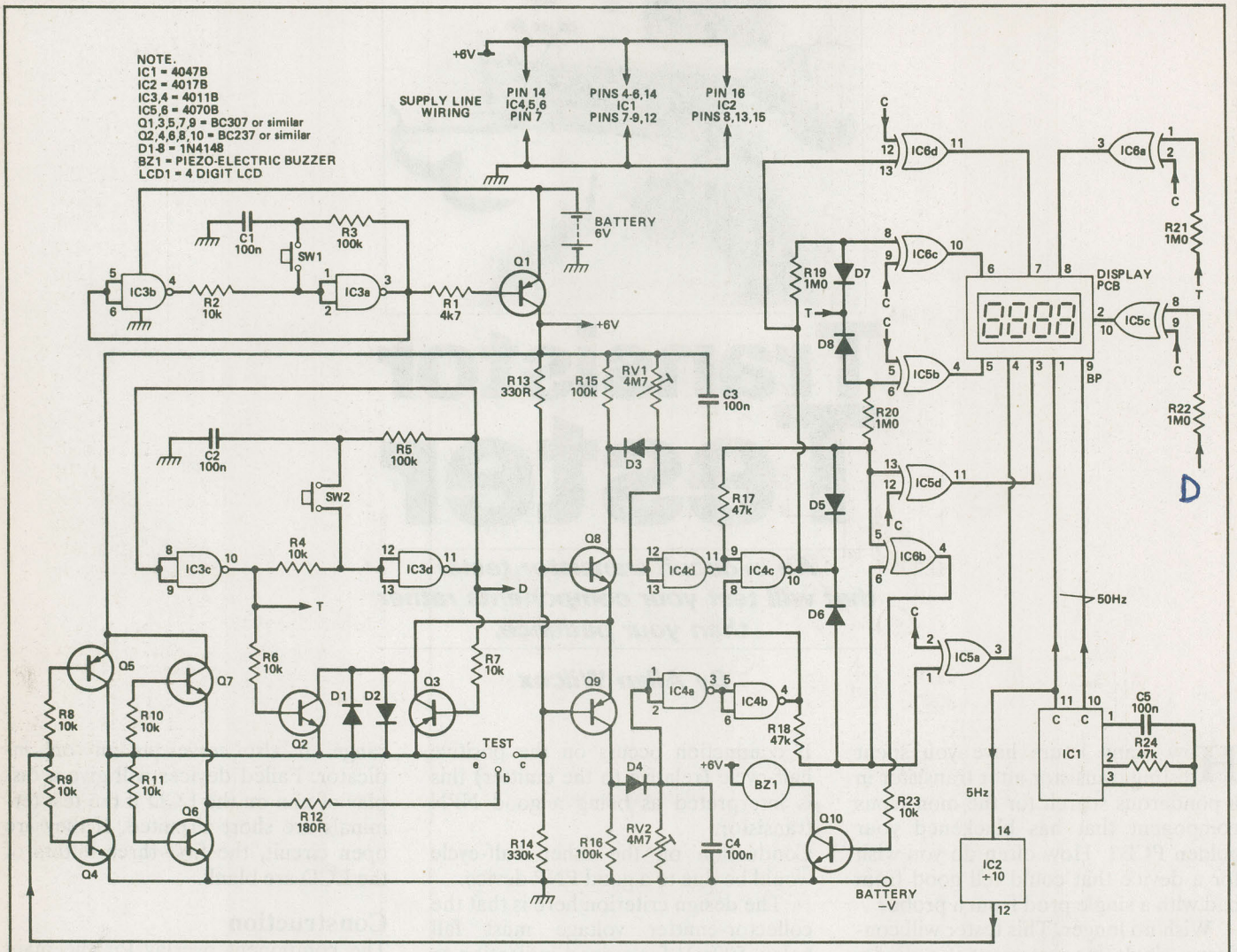
Construction

The component overlay for the main PCB is shown in Fig. 2. All ICs are CMOS and so the usual precautions against static should be taken. Note that they all face the same way on the board.

All odd numbered transistors are PNP and even numbered are NPN. The presets RV1, RV2 may be replaced by 4M7 fixed resistors with just a small increase in the response time resulting.

Avoid any stress on the LCD display, taking care not to overtighten any fixing nuts. The mounting bezel specified comes complete with two socket strips on a board. These were removed and used on the display PCB (fig.3). Take care to observe the polarity of the ribbon cable when connecting the main PCB to the display PCB.

Note that the two switches are momentary push to make, similar to a keyboard type. The ones used on the prototype were from the junk box.



The complete circuit diagram.

Shock, Horror, Probe

Testing a transistor involves connecting into the circuit at three separate points. Manipulating three individual probes with only two individual hands can be a practical problem. To overcome this, a special collector-emitter test probe was constructed using a small Eveready torch case into which were fitted two short lengths of curtain wire to form the probes. Dart points were filed down to fit tightly into these. The result can be seen in the photograph.

The probe used for the base connection is one commercially available. In addition to sockets for the circuit probes, a transistor socket was fitted to the from panel of the case to ease the testing of devices out of circuit.

Testing And Setting Up

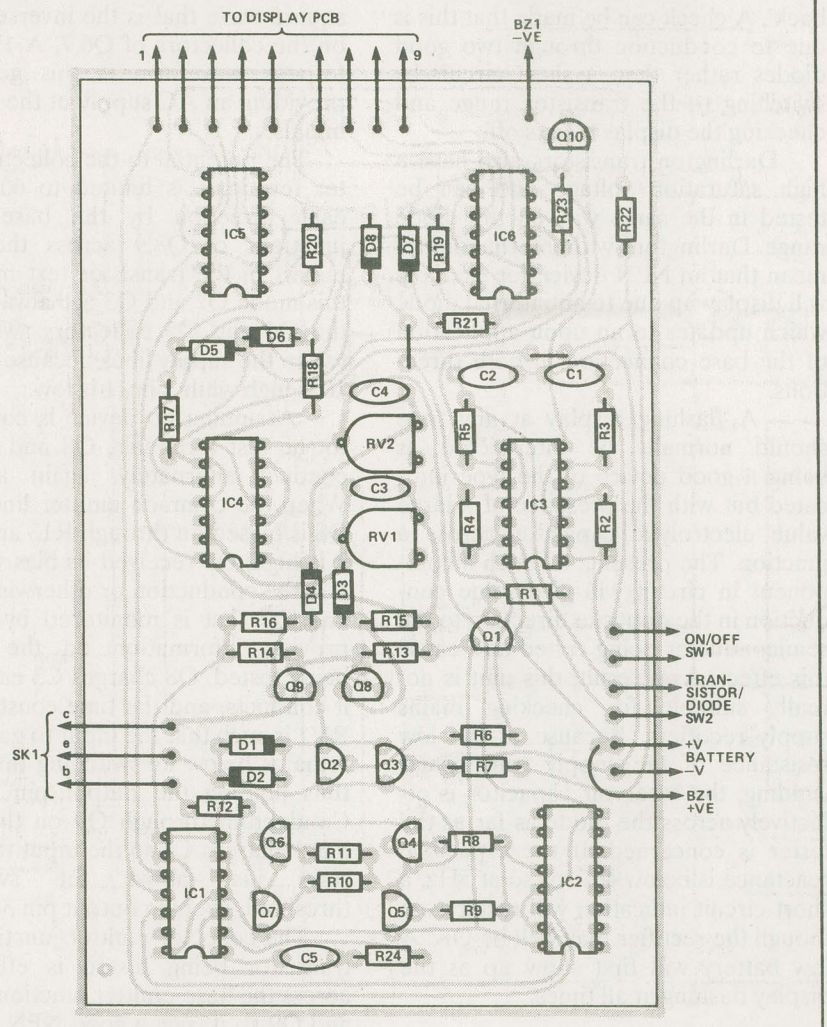
If the presets (RV1,2) are fitted, turn both counterclockwise and connect up the batteries. When on, the display should blank apart from the mode indication which should be a d or t. This should alternate each time SW2 is operated.

Now select the diode mode and advance a preset until the display starts to flash, then back off until the display just blanks. Repeat this procedure with the other preset.

To test the unit connect a diode across the collector-emitter terminals. The display should show **pn** when the diode anode is connected to the collector terminal and **np** when the diode is reversed. There should be no response from the connection of the diode when the unit is in the transistor test mode.

Check the transistor mode using a good transistor of each type. The display should remain blank until the base connection is made. Now short the collector-emitter probes together and check the display shows **nnn**.

Note that the buzzer will sound continuously while a good device of any type is connected. This is useful for rapid testing of components on a board when there is no regard for polarity. Thyristors should be tested on the diode range due to their higher saturation voltage. The collector, emitter and base terminals become anode, cathode and gate respectively. A good device will show pn (it does of course act as a diode) but only when the gate connection is made. Confirm that point otherwise it is faulty. If the



The component overlay the main PCB.

Parts List

Resistors (.25W, 5%)

R1 4k7
R2,4,6-11,23 ..... 10k
R3,5,15,16 ..... 100k
R12..... 180R
R13,14 ..... 330R
R17,18,24..... 47k
R19,20,21,22 ..... 1M0
RV1,2..... 4M7 trim

Capacitors

C1-5 ..... 100n

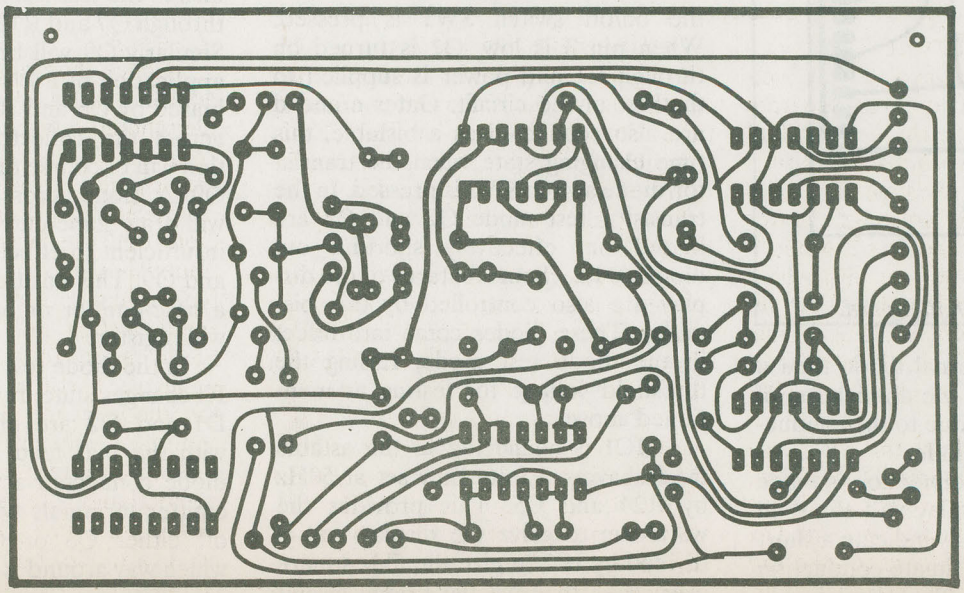
Semiconductors

IC1 ..... 4047B
IC2 ..... 4017B
IC3,4 ..... 4011B
IC5,6 ..... 4070B
Q1,3,5,7,9 ...2N3905 or equiv
Q2,4,6,8,10. 2N3094 or equiv

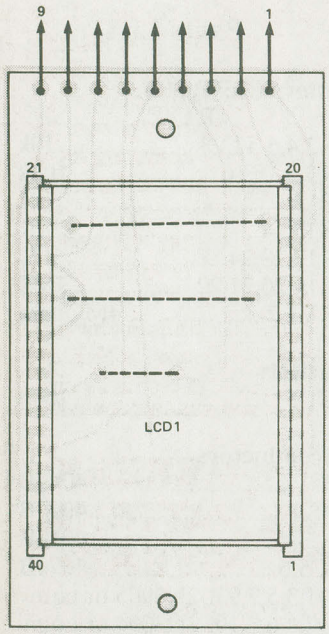
Miscellaneous

BZ1 ..... piezo buzzer
LCD1..... ICM7211AIPL 4-digit direct-drive LCD
SW1,2..... push-to-make

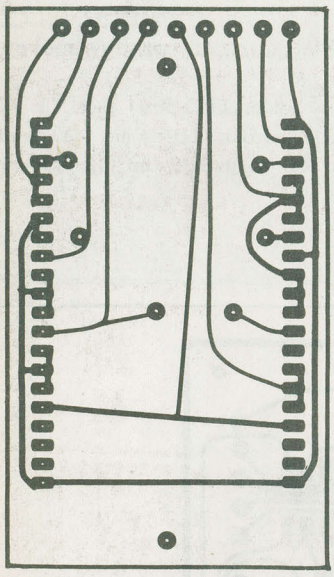
Battery holder, LCD bezel, case. The LCD is available from Electrosonic, 1100 Gordon Baker Rd., Willowdale, Ont. (416) 494- 1555.



The main PCB.



Component overlay for the LCD.



The LCD printed circuit board.

thyristor has an internal diode then it will show np before the application of the gate connection due to the conduction of the internal diode.

Once the gate connection is made in this case, the display will show nn (which would normally indicate a short circuit) due to a legitimate conduction in both directions. The display will similarly show nn when testing two diodes which are connected 'back to back'. A check can be made that this is due to conduction through two good diodes rather than a short circuit by switching to the transistor range and checking the display blanks off.

Darlington transistors also have a high saturation voltage and can be tested in the same way on the diode range. Darlingtons with internal diodes mean that an NPN device for example will display np due to an internal diode which updates to nn upon application of the base connection in both directions.

A flashing display at any time should normally be interpreted as being a good device of the type indicated but with the presence of a large value electrolytic capacitor across a junction. The presence of such a component in circuit will give some conduction in the opposite direction to the semiconductor being tested and cause this effect. As a result, this unit is not really suitable for checking mains supply rectifiers. Because of the low resistance of the supply transformer winding, the reservoir capacitor is effectively across the diode as far as the tester is concerned. If the capacitive reactance is below 40R or so at 5Hz, a short circuit indication will result even though the rectifier may well be OK. A low battery will first show up as the display flashing at all times.

How It Works

Gates a and b in IC3 are wired as a bistable that changes state each time the on/off switch SW1 is pressed. When pin 3 is low, Q1 is turned on through R1 and power is supplied to the rest of the circuit. Gates c and d are also connected as a bistable, this time changing state when the transistor/diode switch SW2 is pressed. In the transistor test mode Q2 and Q3 are biased on, effectively shorting out diodes D1,2. (Some features of the display are also controlled by this bistable). These diodes come into effect in the diode test mode, raising the threshold voltage for testing as mentioned above.

IC1 is connected in the astable mode having a frequency set at 50Hz by R24 and C5. This provides the waveform to drive the display and is divided by IC2 to give the 5Hz square wave used to drive the bridge circuit formed by Q4-7. The result of this is that the collectors of Q4,5 have a 5Hz square wave that is the inverse of that on the collectors of Q6,7. A 1V peak-to-peak waveform is this generated providing an AC supply ot the test terminals.

The potential to the collector-emitter terminals is limited to 600mV in each direction by the base-emitter junctions of Q8,9 across these terminals in the transistor text mode. In this mode Q2 and Q3 are always on as the Q4 and Q5 collectors switch between the supply lines because IC3 pin 10 is high while pin 11 is low.

Assuming no device is connected tot he test terminals, Q8 and Q9 will conduct alternately, again at 5Hz. When the common emitter line is low Q8 is biased on through R13 and when it is high, Q9 received its bias via R14. It is the conduction or otherwise of Q8 and Q9 that is monitored by IC4 to provide information on the device being tested. Q8 charges C3 each time it conducts, and the time constant C3-RV1 is such that the input to gate IC4d remains below its switching threshold, thus holding the output pin 1 high. Conduction through Q9 on the other hand charges C4 so the input to gate a stays just above the switching threshold, keeping output pin 3 low.

The collector-emitter junction of a transistor being tested is effectively across the base-emitter junctions of Q8 and Q9 so if, say, a good NPN transistor is in circuit the bias to Q8 is diverted and it will switch off. Forward bias to the test transistor at this time is through Q7 and R12.

Similarly Q9 will be turned off by the application of a PNP device, this time biased by Q6 and R12. A short circuit across the collector-emitter connection will of course turn off both Q8 and Q9. A diode across these connections will draw some current but this will be insufficient to effect conduction of Q8 and Q9. This ensures a transistor with a base-emitter or base-collector short will register.

In the diode test mode, the bistable IC changes state, reverse biasing Q2,3. D1 and D2 are effectively in series with the bias feed to Q8 and Q9. A diode connected across the collector-emitter terminals will be able to turn off either Q8 or Q9 depending on which way around is connected.

The time constant RV1-C3 and RV2-C4 is dictated by the choice of

5Hz as the rate at which the supply to the test terminals is reversed. This in turn is a trade off between the response time of the instrument and reasonable immunity to the effect of any large value electrolytic capacitor that may be in circuit across a junction.

Good immunity to in-circuit resistance is achieved because the resistance across the junction must fall below one tenth of the value of R13, 14in the case of the collector-emitter connection and one tenth of R 12 in the case of the base-emitter connection before the conduction of Q8,9 or the transistor being tested is affected.

In-circuit resistance below this will reduce the bias in each case to under the 600mV required for conduction.
A conventional 4-digit LCD us used to indicate the status of the deice being tested. The display is driven by a perfect square wave from the bistable output of IC1. The individual segments required to represent the desired letters are driven by the exclusive-OR gates of IC5 and IC6.

The clock output from pin 10 of IC1 is connected to one input of each EX-OR gate and also to the backplate of the LCD. If the second input to any gate goes high, a square wave will then turn on any segments connected to the output of that gate.

Open circuit across the test connections blanks the first three letters of the LCD since both inputs to IC4 from Q8 and Q9 are high, forcing a low on pin 10 and the five control inputs of the relevant gates. If a good NPN transistor is tested, Q8 turns off, sending the output of IC4d low and IC4c high, displaying nnn and releasing control of the lines through R17 and R18. Since Q9 is o, IC4b is high and the display npn is completed.

With a PNP transistor, the output of IC4b goes low as Q9 turns off, leaving n showing on the second digit. A p is completed each side from IC5b and IC5d, since the output IC4d is high.
In short circuit, both Q8 and Q9 are off, sending the lines through R17 and R18 low. This leaves a display of nnn from the high output of IC4c.

In the diode mode, the first digit of the LCD is blanked by sending the control inputs of IC5b and IC6c low through D7 and D8. The bistable ICs turns off Q2 and Q3 placing diodes D1 and D2 in series with the bias path to Q8 and Q9. The voltage across the collector-emitter test connections is now about 1.2v and the application of a diode will cause the cutoff either Q8 or Q9 depending on its direction. This displays either pn or np as described above.

The buzzer sounds if the inputs of gate IC6b are different, which only occurs when a good device is in circuit. ■

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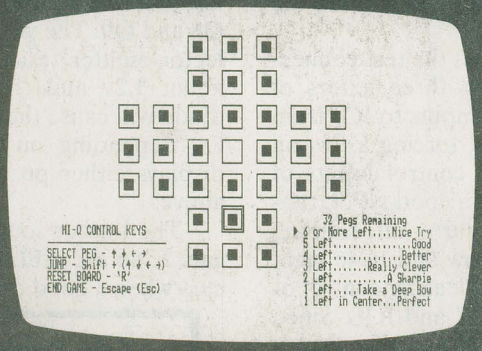
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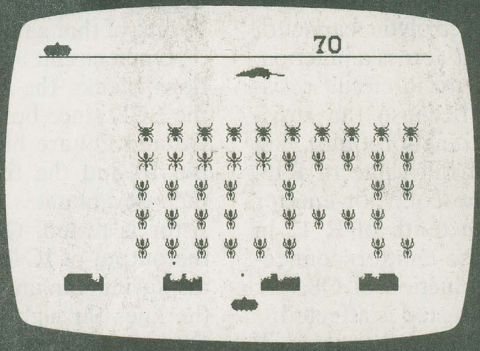
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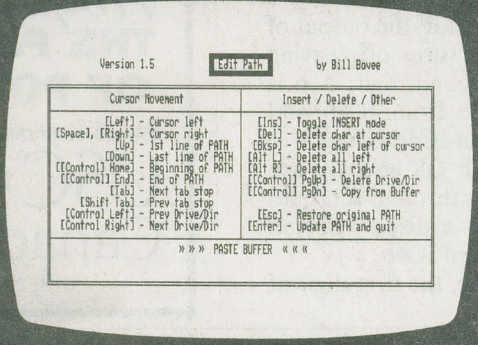
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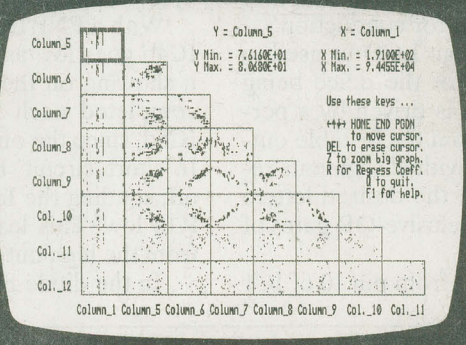




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And Even More games! You get NFL Football; SOPWITH2 flight simulator, GOMOKU, an ancient strategy gamee; TICK, space invaders with a twist; an EGA solar system simulator; HIQ for the intellect and KILLER. CGA required.

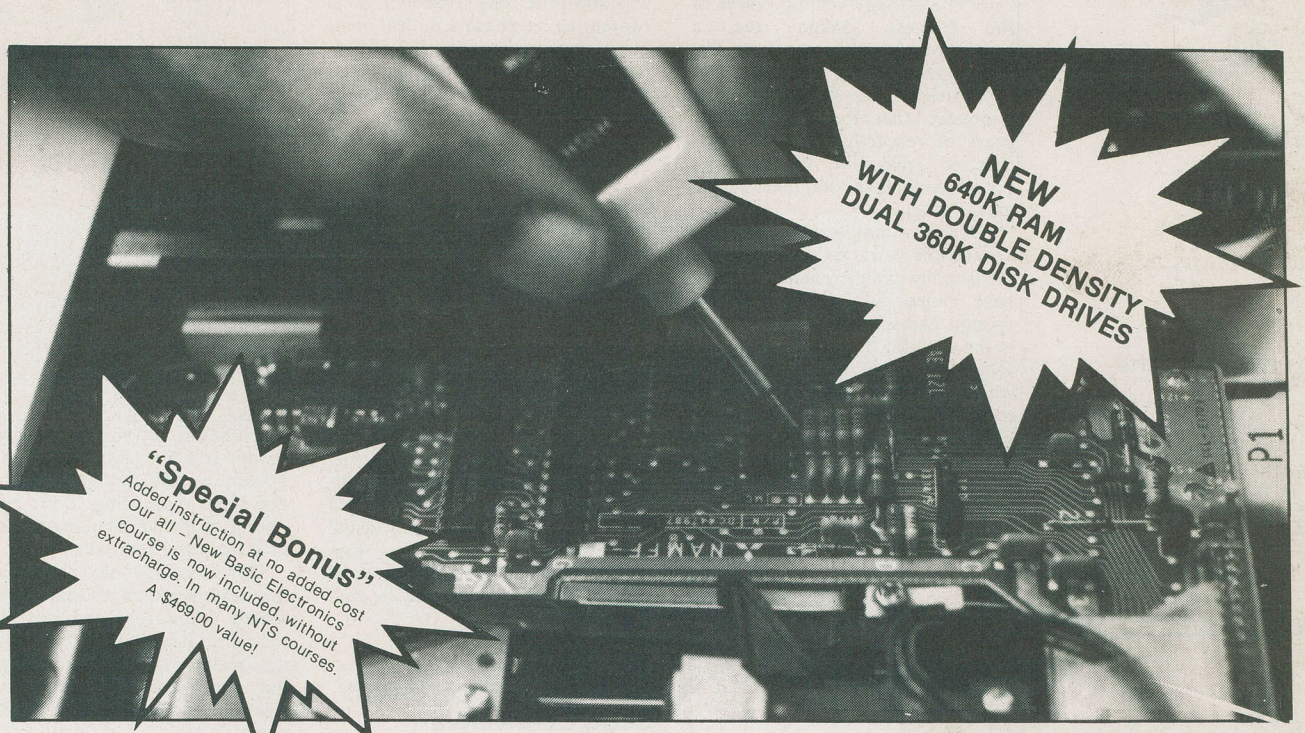
SuperDisk 8

A grab bag of utilities, games and just plain fun! You get WCD, a utility that calculates flying times and distances between various world cities; HLPURSLF, a resident on-line help system that lets you create your own help screens; UNIX, a nice PinBall game; TAO, spiritual wisdom; EP, a nice PATH editor; VDE, a small WordStar- like text editor and HAVE, a system environment checker.

SuperDisk 9

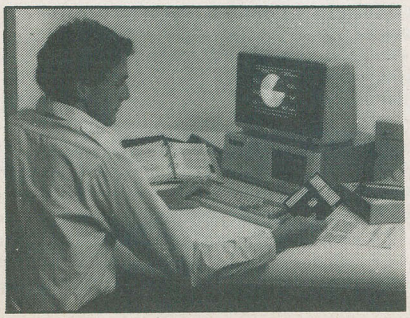
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The Scientists Tell Me...

By David Dempster

Getting Well With the Ginko Tree

For more than 5,000 years the Chinese have used ginkgo leaf extract because of its unique healing powers. In fact, so popular is the medicinal properties of the ginkgo, Europeans and Asians spend over $640 million annually on over-the-counter ginkgolide compounds. Doctors in Europe and Asia prescribe ginkgolides for a variety of diseases, from asthma to Alzheimers.

But now a Harvard University professor and his colleagues have synthesized a chemical that replicates the ancient healing power of the Chinese ginkgo tree, a breakthrough that could have important medical applications.

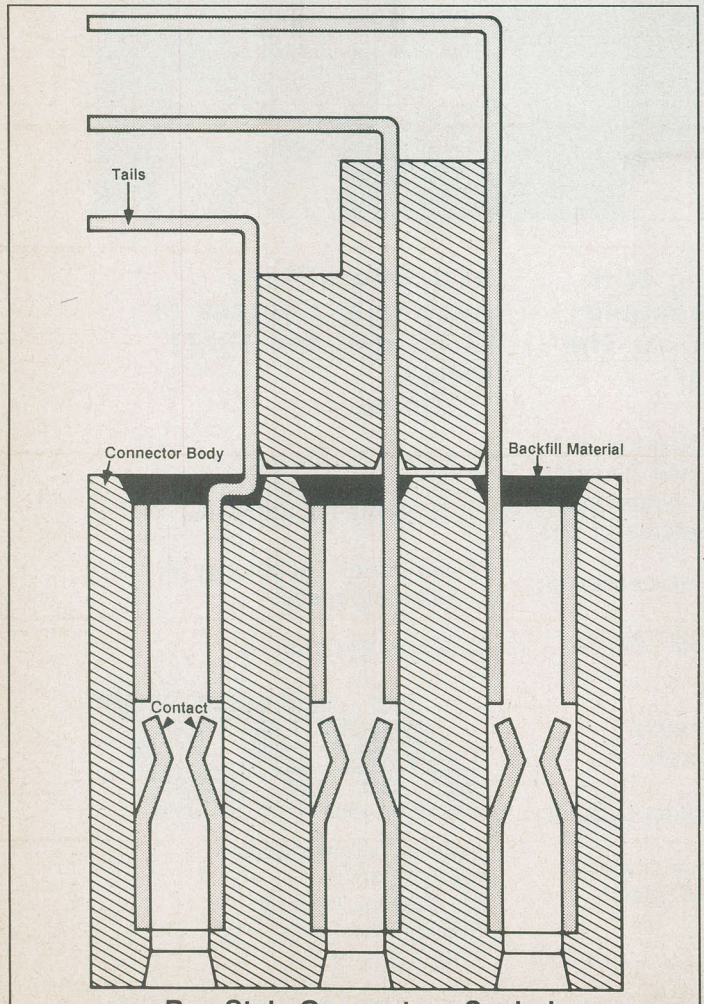
Professor Elias J. Corey recently announced that after more than two years of research, they have synthesized ginkgolide B, the most potent medicinal compound in the ginkgo tree.

Despite attempts by laboratories around the world to synthesize the medicinally potent chemical, most have failed and thrown in the sponge. Not so Professor Corey. He is the Sheldon Emery Professor of Organic Chemistry and his lab, which has synthesized more than 80 complex molecules in the past 30 years. Corey says tha ability to make the chemical will help scientists evaluate the specific health benefits of each ginkgolide compound and make it easier for drug companies to obtain large amounts of those that are most promising. Without this capability, only small amounts of the compound can be extracted from the leaves by a time-consuming process.

However, says Corey and other researchers, medical application of the synthetic chemical is still some way down the road. However, he is content to let pharmaceutical companies explore its potential for future medical use while he concentrates on the synthesis of similar molecules.

"My lab provides the chemistry to make it possible to synthesize similar, but simpler, related molecular structures whose therapeutical use may be even greater than ginkgolide B," said Corey. "Our role was the discovery."

Corey is of the opinion that the ginkgolide B discovery may have many applications. Doctors in England have already tested ginkgolide B on humans, for treating asthma and allergy-type responses. The positive results, which agree with many centuries of casual observation, suggest that ginkgolides could make good medicines for those maladies, says Corey and others.



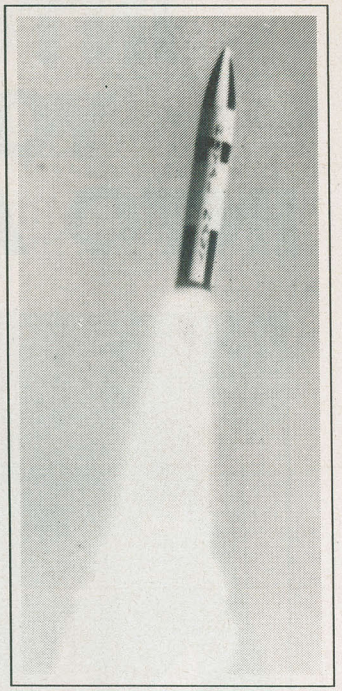
Box Style Connector - Sealed

UV Curable Encapsulant Seals Connectors

The post and box style connectors widely used for today's multiple lead printing wiring assemblies pose new challenges for protective conformal coating. An unsealed connector can open a pathway for unwanted moisture and contaminant to reach the circuitry. Additionally, during the coating process material can wick into the contact area and interfere with the insertion of mating parts, forcing manufacturers to scrap boards worth thousands of dollars.

But now there is an answer to the problem. A new encapsulating material has been developed to overcome these difficulties. An ultraviolet heat curable encapsulant is especially designed to backfill or preseal connectors which can then be used for printed wiring assemblies requiring conformal coating.

A product of Dow Corning, the encapsulant is a methacrylated/acrylated urethane supplied in one component. It is dispensed directly into the contact tail and cavity area and is formulated to be used in automated dispensing systems. The thixotropic material, known as UVEXS 605-A, flows just far enough into the connector cavity to seal it before returning to a high viscosity. It cures in seconds on exposure to UV radiation and the one-step dispensing and curing operation is said to be accomplished in as little as 15 seconds.



Dow Corning is also developing a new testing system to locate leaks in sealed connectors and determine their size. It is claimed the new testing device will overcome many of the problems associated with solenoids, and will verify that a connector is sealed in a fraction of the time previously required.

New technologies Needed for Future Space Missions

New rocket engines that can carry heavier payloads into higher orbits at lower cost, nuclear propulsion and power systems, and flexible robots that can maneuver in zero gravity — these and more are some of the new technologies needed in years ahead if the United States wishes to retain its competitive status in space. So says a National Research Council Committee in their report to the National Aeronautics and Space Administration (NASA). The committee pointed out that many basic research programs were terminated or allowed to wither before he technologies were ready for use. Since the close of the Apollo program, it added, "little has been done to enhance or develop the basic technologies that will enable future missions or provide the nation with a variety of options for the space program. The shuttle, itself, was built largely with existing technology."

The committee recommended that NASA place its highest priority on advanced propulsion technologies. The space shuttle main engine is the only significant development in space propulsion for the past 20 years, the committee said.

Although Saturn heavy-lift vehicles has been successfully deployed, they have been discontinued, as have research programs in nuclear propulsion. If United States wants to explore nuclear-propelled spacecraft, the report says that the country must start over because much of the technical base was lost.

Facilities were mothballed or converted to other uses. Today a great deal of the present knowledge "resides in memories of now retiring scientists, metallurgists, and engineers," the committee stated.

What does all of this mean in dollars? The committee sees the need for the U.S. to retain its competitive status, not necessarily its pre-eminence. For the past eight years, the U.S. has ejoyed a positive balance of trade in aerospace with a surplus of more than $10 billion (US) annually. But now there is strong competition from Europe, Japan, and the Soviet Union.

And the solution. According to the committee, 7 percent of NASA's budget should be allocated to R & D over the next decade to help develop breakthrough advances. As well, such funds should be protected from short-term requirements of special operations such as the space station.

In making its selections, the panel of 16 aerospace experts considered future demands in four co-called "driver missions": space science, national security, and humans-in-space. It identified eight key technologies that, it said, had been "relatively neglected" during the past decade or longer. According to the committee, advances will be needed in propulsion, technology for humans in space, life support systems, automation and robotics, power, materials and structures, information and control systems, and sensors.

Space transportation. Future missions will require reusable, economical engines that can put humans into space and return them to Earth; and rockets to boost payloads from low to high orbits. If humans are to be involved in long missions, to Mars, for example, high-thrust systems with shorter transmit times will be needed, the committee said. Planned for the late 1990's, work on the main engine would have to begin immediately, it said.

Space Science. Among space science missions the committee identified as technology "drivers" for the mid-1990's are the Earth Observing System, a group of telescopes in space to study the Earth's atmosphere, surface, and interior; the Large Deployable Reflector, a space telescope about 10 times larger than the Hubble Space Telescope that would have to be assembled in space; and the Mars Sample Return Mission to collect samples of the Martian surface and bring them back to Earth.

Looking ahead to the early 21st century, the committee urged NASA to begin now to develop technologies for larger arrays of telescopes in space, solar probes, Venus sample return, and human exploration of Mars.

Humans in Space. The committee identified research needed in physiology, psychology, and sociology to better support humans in a space environment. Humans will be involved in a number of proposed missions from constructing a space station in the 1990's to that possible manned mission to Mars in the early years of the 21st century. New technologies needed for space station work include improved space suits and "space taxis" for out-of-craft activities, better protection against cosmic radiation, and fine-tuned robots. New technologies needed for a Mars mission include environmental systems that generate or recycle their own air, eat, water, and food; better technologies for handling human waste; and use of resources found in space to resupply colonies on Mars and the moon.

National Security: While civilian space pursuits are NASA's principal concern, the agency can contribute technical know-how to some areas of national security such as developing clearer and more reliable communications; remote sensing of the oceans; low- cost, heavy-lift space vehicles; and advanced composite materials.

And in some of the foregoing, it could be that Canada could continue to play a role, as it has in the past with Spar Aerospace's Canadarm and the University of Toronto's Aerospace Institute. Who knows what tomorrow will bring? ■

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How VCRs Work



Courtesy JVC Canada

Follow along on a trip through the inner workings of one of the most popular home entertainment devices.

By Timothy B. Palmer-Benson

Despite their flimsy plastic facias and fluorescent flashing displays, VCRs are little miracles of electronic and mechanical engineering. It is true they are known for producing waxy faces, color shifts, poor resolution and picture noise but on the other hand as one broadcasting engineer told me; "they are still not that bad and they are getting better." The latest VCRs introduced by Sony and JVC prove that an already sophisticated and complicated recording process can be improved to yield results that match or exceed the performance of the laser disc. In order to appreciate how these new machines work, it is necessary to first understand some of the basics of video tape recording. You'll also be able to appreciate what is hype and what is a real improvement.

A video cassette machine is basically an audio tape recorder with helical scanning video heads. (A helix resembles a coil or spring.) Instead of the tape passing at right angles in front of a head as in audio cassettes and open reels, a minimum of two heads are used (except for Sony's Beta movie camcorder) and the tape is looped in something akin to an omega shape around a drum or cylinder that rotates at high speed.

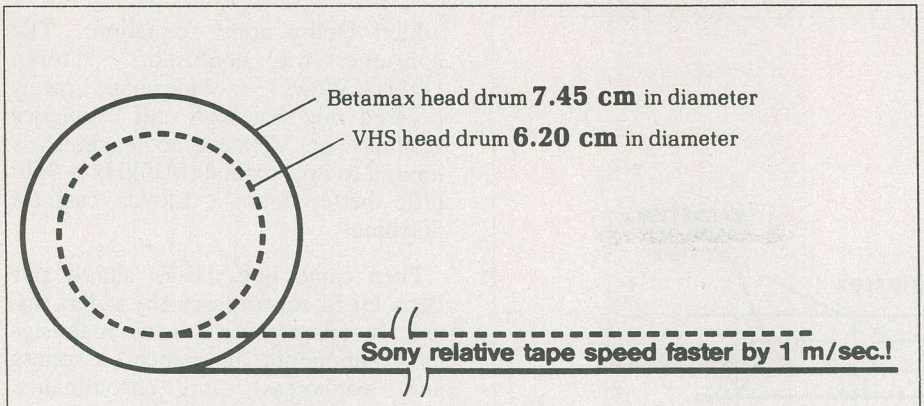
The drum is mounted at an angle (approximately 6°) so that a pair of video heads, mounted on its surface 180° apart, move in a helical fashion as the drum rotates. The angle of the drum, as well as some tape guides, force the tape to touch the bottom part of the drum when it first makes contact and to leave the drum at its top. This results in the two heads either recording or picking up a continuous series of slanted or diagonal signal tracks. In VHS and Beta machines, a track is scanned or recorded at the rate of one every 1/60th of a second by two heads. As the one head completes a track, a second is beginning a second track and so on. Two tracks or fields make up a single frame of a television picture.

Although VCRs are precision pieces of equipment and tolerances are measured in microns, the laying down of tracks next to each other still poses some problems especially since the width of the tracks is so small. Each track on a Beta Two tape, for example, is only 0.03 mm wide! How is it possible that the heads are able to scan the same tracks exactly on playback or to pick up the tracks made by another machine? This has been made especially tricky in consumer VCRs since the so called "guard bands", used in professional machines to separating each track, have been eliminated to make more efficient use of tape. And, how are slight speed differences between machines resolved? The answer to these problems are taken care of with servo systems, control heads, phase inversion and azimuth recording.

Azimuth Recording

In azimuth recording, the angle of the gap in each pair of video heads is mismatched slightly so that each head can only record and pick up high frequencies from the track made by that particular head. Thus in a sequence of tracks, head A will pick up information from track one and three, while head B, on the other side of the head drum will pick up tracks two and four. In 8mm camcorders the head gaps are angled away at +12° and -12°. On Beta machines, the head gaps are angled away from the perpendicular by +7° and -7° while VHS uses +6° and -6°. A strong signal is received from a particular track only when it is scan by a head having the same azimuth. It may scan a bit of an adjacent track but high frequencies won't be picked up because the azimuth in the adjacent track will always be different.

There is another means of ensuring that only the right track gets picked up at any given time and that is with phase- inversion recording. Again it is used by both VHS and Beta and is designed to take care of that portion of the video signal that is so low in frequency that azimuth recording won't



The relationship between Betamax and VHS head drum sizes

Courtesy Sony Canada Inc.

work so well. It achieves the same end - reducing crosstalk between adjacent tracks - by shifting the phase of the lower frequencies (in this case the chrominance signal) by 180° for each track in Beta, and by 90° for each track in VHS. Having adjacent tracks recorded with different phase relationships helps to prevent the video head from picking up information from an adjacent track.

Speed and Heads

Speed accuracy is also very important in VCRs and it's taken care of with various servo systems. Sync pulses that are part of the video signal are used to synchronize the speed of the head drum with the movement of the tape. The pulses, (a 60Hz square wave), are recorded onto a stationary or longitudinal track along the edge of the tape by a control head. This occurs after the tape has left the head drum and is on its way to the take up reel. When a tape is played back, these control pulses (square waves) are detected at the control head. If the shape of the square wave is altered because the mechanism is running too fast or too slow, this distortion of the wave will cause a servo system to adjust the speed of the capstan motor. A tracking control is provided to compensate between slight distortions in square recorded by different machines.

VCRs depend very much on something called "relative speed" to achieve wideband frequency response. Because the heads on the drum are whizzing around at a tremendous rate (1,800 rpm) in a helical fashion, they are able to "simulate" a high recording speed. (The 1,800 rpm is enough to cause the tape to ride on a cushion of air as it travels around the head drum at the infinitesimal distance of only 35 microns. Only the heads are actually in contact with the tape.) This relative speed or "writing speed" as its called, along with special heads helps to ensure that video's high frequency information, which extends out to beyond 4 MHz, is recorded onto a tape even though it is moving passed any given point in the VCR at less than the speed of an audio cassette. (VHS SP or Standard Play speed is 1.31 ips, while Beta's popular Beta Two speed is 0.79 ips.) All video cassette recorders, even the 8mm camcorders, use this system for recording the video portion of a signal though drum sizes are different.

Naturally, this is not the complete story in the process of getting a video signal on or off a piece of tape. Merely spinning a drum containing record/playback heads won't accomplish much unless the heads are specially designed for recording high frequency information. Also the video signal must be "treated" before it gets to the heads in order to ensure equal amplitude or strength for its various components.

If you remember the theory behind recording heads in audio tape recorders, you'll know that as the gap between opposing poles in the head becomes smaller, the greater the ability for the machine to reproduce and record high frequencies. It's the same in video which has taken things somewhat further. Modern manufacturing has managed to produce a gap that is so small that it can be seen only with a powerful microscope. The gap is so small (typically .6 microns) that it ap-

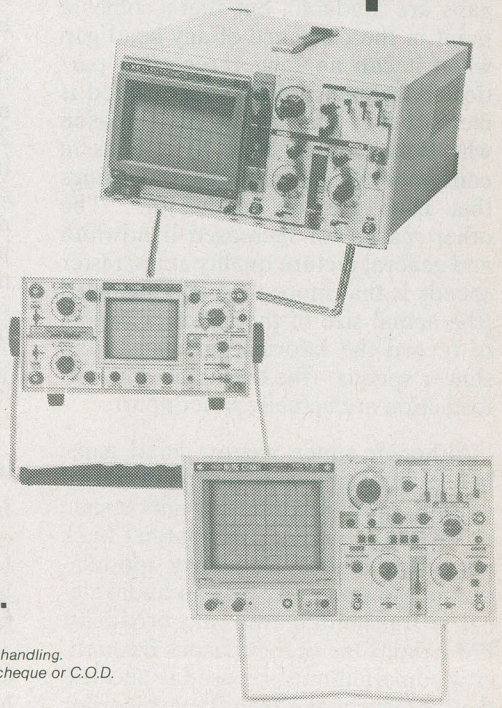
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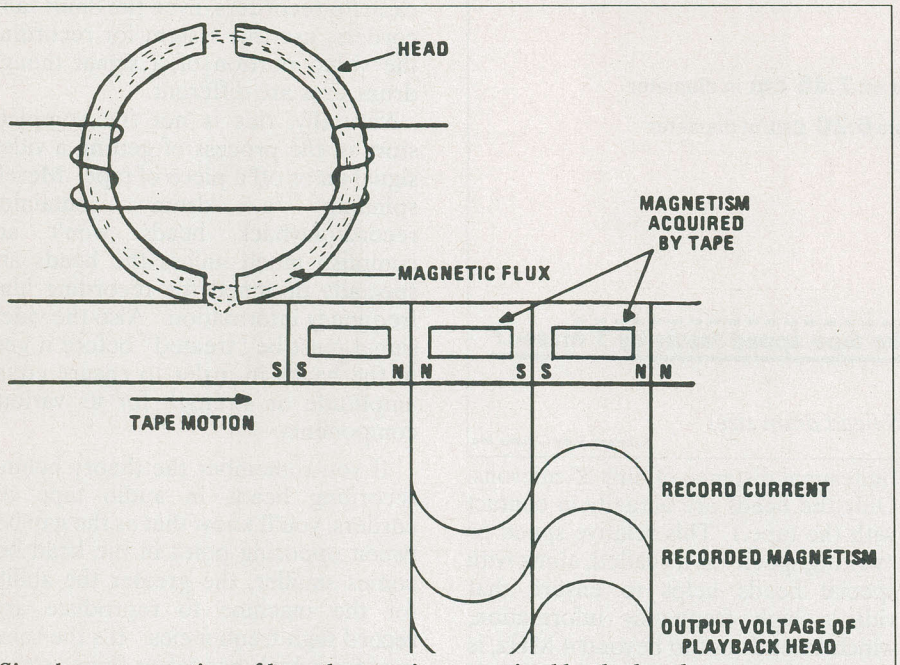


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Simple representation of how the tape is magnetized by the head. Courtesy Sony Canada Inc.

proaches the same gap contained in a 4 MHz sine wave displayed on an oscilloscope. If you've ever seen even a 1 MHz signal displayed on an oscilloscope, you'll really appreciate how small these gaps are! Another way of illustrating these head gaps is to compare them with the 100 micron diameter of a human hair. Small head gaps are laudable, but there comes a point in the existence of any head gap when it can no longer record a particular frequency unless tape speed is increased. This is the main reason why Beta One or VHS SP speeds in consumer VCRs produce recordings that have greater bandwidth. The other reason for increased bandwidth and general picture quality at the faster speeds is that more tape is being used (the actual size of the heads is larger) to record the information than at the slower speeds - the tracks of video information are actually wider apart.

Although super narrow head gaps, helical scanning and fast play/record writing speeds are of major importance in VCRs the system still wouldn't work properly without frequency modulation in the same way that an audio signal is transmitted over the broadcast FM band. One of the reasons frequency modulation must be used is because the output voltage from tape recorder heads varies with frequency and the frequencies involved here are particularly high. Another reason is that FM ignores random amplitude variations in playback signals. A tape can be driven into saturation during signal peaks and any amplitude distortion is simply ignored.

There are many similarities between the Beta and VHS systems but at the same time there are some major differences particularly in the way tape is handled. Until just recently for example, you couldn't fast cue in VHS the way you can in Beta. Beta machines use a head drum that's about 20% larger than a VHS one. If you go back to the discussion of "relative speed" you'll realize that a larger drum means a higher relative speed, or writing speed, and a higher writing speed means better high end frequency response for the video signal. Both formats use azimuth and phase inversion techniques and frequency modulate the video signal before it's put onto tape.

Audio Techniques

In audio, both formats began with so called "drag heads" or "longitudinal heads" mounted in part of the control head. But because the speed of the tape is so slow, frequency response was and still is limited despite equalization circuitry. Noise levels are high. VHS has followed with stereo longitudinal heads but with two tracks of hiss, the noise becomes intolerable, so in addition to equalizing the signal VHS has added Dolby noise reduction. The consumer was confused: "Stereo Dolby....Wow!" Salesman rarely pointed out that high end frequency response on VHS stereo machines is limited to approximately 10kHz +3db, little better than a Lloyds cassette machine!

Then came Beta Hi-Fi; simply put Beta Hi-Fi reprocesses the video signal. It separates video's two main signal components, luminance (crispness and brightness) and chrominance (color), to squeeze a frequency modulated stereo signal in between. Then everything gets recorded on the video heads just as before. This method results in a wide band audio response of 20Hz to 20kHz, a dynamic range of more than 80 dB and very low wow and flutter. While this is still not hi-fi in the true sense of the word Beta Hi-Fi is quite satisfactory for watching movies. JVC followed Sony's lead with VHS Hi-Fi and obtained similar specs. But, JVC was forced to use a more complex system because of the way the VHS video signal must be recorded onto tape. There isn't room in VHS signal to squeeze in an FM audio signal and so VHS uses "depth multiplex recording," In this system, the audio is frequency modulated and then sent to separate audio heads positioned 180° apart on the head drum. The process uses the entire tape width to lay down the information but because the azimuth of the head gaps is different (+30° and - 30°) the audio is not picked up by the video heads. The requirement for two additional heads naturally raises the cost of VHS Hi-Fi machines over their Beta counterparts. As you can imagine, the tolerances involved here have become much tighter. If you've ever wondered why some VHS Hi-Fi movies seem to be afflicted with unexplained sputtering on their hi-fi tracks these tolerances are the reason. It only take's a dubbing house to have machines that are slightly out of adjustment and the hi-fi track is ruined. When you're dealing in microns it can happen!

Higher Technology

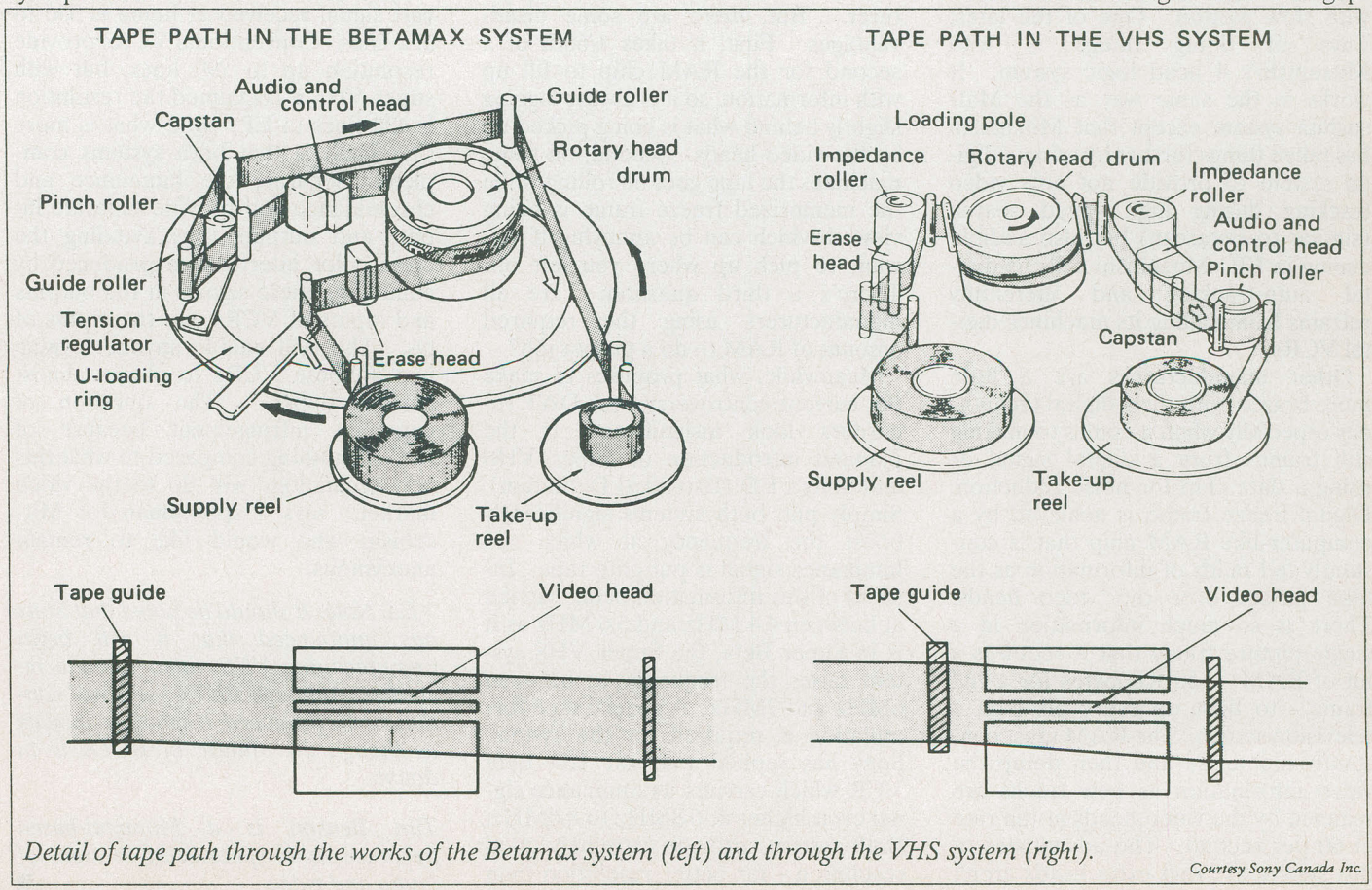
Back in video, Sony's Beta system continues to lead the way in pure technology even if Sony can't do so well in sales. Sony's first step was Super Beta. In this system the frequencies of the luminance signals are boosted by

800kHz resulting in a 20% increase in resolution. Only the luminance part of the signal, the part that gives you that crisper, clearer picture, gets boosted. You get 290 lines of resolution with a Super Beta VCR compared to 240 lines for regular Beta. JVC's reply was HQ (High Quality). This is a package of improvements that include a reduction in noise levels contained in the luminance and chrominance signals as well as an increase in the ceiling or what is termed "the white clip level" of the video. On VHS VCRs without HQ images that have bright edges against a dark background tend to smear because the full video wave form has been clipped in order to get it recorded onto tape. Raising the white clip level enhances the apparent contrast and detail in the picture. Despite these improvements, the horizontal resolution of HQ remains at 240 lines as opposed to Super Beta's 290. On the other hand, VHS HQ is completely compatible with regular VHS while Super Beta sometimes causes difficulty for standard Beta machines because they don't have video heads capable of picking up the higher frequencies used by Super Beta.

No look at how VCRs work would be complete without mentioning the battle for over the video heads themselves, freeze frames and slow motion. Thanks to manufacturing hype, the average VCR buyer has been left with the impression that the more heads a machine has the better its performance but if you've understood this article you'll know that you can only use two heads at a time and that extra heads (aside from the ones for VHS Hi-Fi) are for special effects only. A single pair of heads won't work because when the tape is stopped only one of the heads can scan a track accurately. The other head is unable to pick up the video information because its azimuth setting is wrong, but with one or more heads a second reading of a particular track becomes possible and thus a full frame for a tv is obtained since two fields, or track scans, make up a frame.

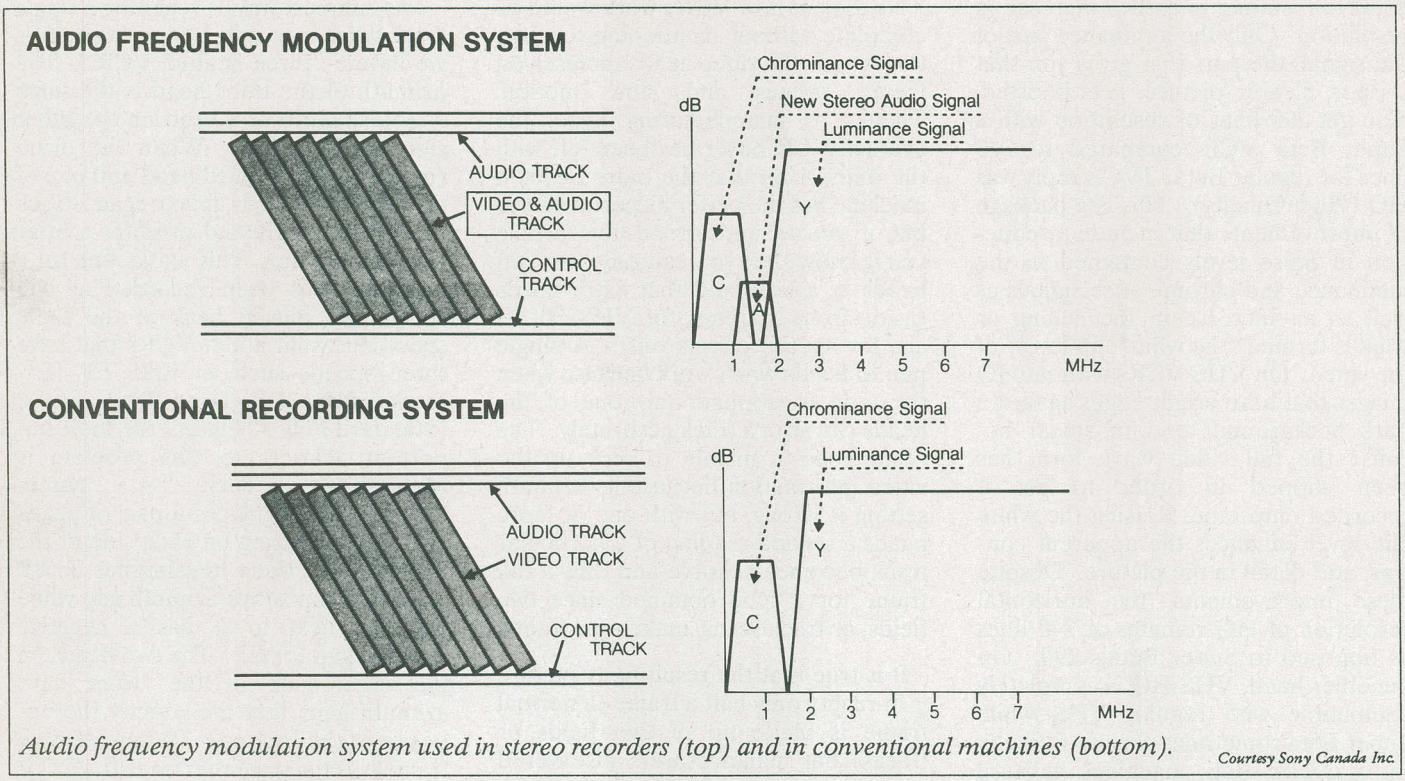
It is true that the resulting tv picture is in reality only half a frame (a normal frame is made up of two fields or tracks) but manufacturers discovered several years ago that a single field, scanned twice gives the best jitter free picture.

The simplest way of scanning a single track twice is to add a third head, thus we have a "three headed VCR." The azimuth of the third head is the same as the azimuth of a head on the other side of the drum. When the drum rotates both this third head and one of the regular heads is able to scan a track or field perfectly and produce a jitter free still picture. This works fine for a tape that has been recorded at one speed and played back at the same speed but what about VCRs that have three speeds such as VHS EP (Extended Play), LP (Long Play) and SP (Standard Play)? One of the most important answers to this problem is Matsushita's Tech 4 system (Panasonic). It places a pair of heads in a single housing on each side of the head drum. Each housing has an SP head with a positive azimuth gap while the one next to it has a negative azimuth gap for EP. The two heads on the other side of the drum have azimuth gaps that are exactly the opposite of the first pair. When a freeze frame is required either an extra EP or an extra SP head is switched in electronically to provide that second, crucial scan of a single track. The gap



Detail of tape path through the works of the Betamax system (left) and through the VHS system (right).

Courtesy Sony Canada Inc.



Audio frequency modulation system used in stereo recorders (top) and in conventional machines (bottom). Courtesy Sony Canada Inc.

on each head is carefully chosen so that good results are obtained not only with still frames on each speed but also with slow motion. One of the latest ways of doing things is with Mitsubishi's 4 head logic system. It works in the same way as the Matsushita system except that Mitsubishi has taken things further by using a digital system to provide not only video tracking during high speed search (similar to Betascan) but also audible cueing in EP. Mitsubishi calls its digital auto-tracking and mercifully refrains from calling its machines digital VCRs.

Other manufacturers are a little more brazen with their digital technology especially when it comes to making still frames from a digital signal or using a data chip for noise reduction. Digital freeze frame is achieved by a computer-like RAM chip that is constantly fed fields of information as the tape passes over the video heads. There is so much information in a single picture frame that it requires a lot of RAM - 550 Kilobytes for a full frame - to light up every pixel on a television screen. The RAM must constantly memorize and then dump the video information as new tracks are scanned by the video heads at the rate of 60 per second. The advantages of this system are that extra heads aren't needed and special features like picture-in-a-picture (PIP for short) come at very little extra cost to the manufacturer. But, there are some disadvantages. First, it takes 1/60th of a second for the RAM chip to fill up with information, so it is always lagging slightly behind what is being picked up by the video heads. Second, on some machines the tape goes on rolling while the memorized freeze frame is being viewed which can be annoying if you want to pick up where you left off. There's a third question; are all manufacturers using the required amount of RAM to do a proper job?

Meanwhile, what promises to make the current controversy over DAT recorders look insignificant, is the planned introduction of Super VHS and Sony's ED (Extended Definition). Simply put, both systems significantly boost the frequency at which the luminance signal is put onto tape. Instead of this information being carried at between 4.4 MHz and 5.6 MHz as it is in Super Beta, the Super VHS system raises the frequency to between 6MHz and 7MHz. A special tape formulation is required for the system. Sony has replied with the ED Beta VCR which carriers its luminance signal even higher at 6.8MHz to 8.6MHz. Both systems provide extremely good resolution - far better resolution than what is obtainable off air with the best possible broadcast signal. For example, typical resolution for a broadcast signal received at home is 330 to 350 lines. Conventional VCRs provide resolution up to 290 lines, but with super VHS it is claimed the resolution is 430 lines in EP! But, what is more significant is that both systems completely separate the luminance and chrominance and provide separate inputs and outputs thus avoiding the cross color interference produced by combining these signals at the outputs and inputs of VCRs and the inputs of tvs. This will enable anyone owning two of these VCRs to obtain almost perfect dubs. "The question of copyright infringement because of DAT is nothing compared to what this new technology will do to the video market," says a spokesman for Mitsubishi who would like to remain anonymous.

Ed. Note: It should be noted that Sony has announced that it will begin manufacturing VHS video cassette recorders. Although BETA units will continue to be produced, it certainly appears as though the future of BETA is in doubt.

Tim Benson is a Montreal-based freelance writer specializing in areas of audio and video. ■

Introducing Microprocessors Part 2

The basic terms of the microprocessor system.

By Mike Tooley

Learning Objectives

The general learning objectives for part two of *Introducing Microprocessors* is that readers should be able to:

(a) draw a block diagram showing the internal architecture of a representative 8-bit microprocessor and state the function of each of the principal internal elements (2.1)

(b) state and explain the function of each of the principal external connections of a representative 8-bit microprocessor (2.1)

(c) explain the need for a clock and state typical frequencies and periodic times for microprocessor clocks (2.1)

(d) make appropriate use of manufacturers' data sheets (2.1)

The specific objectives for the part are as follows:

2.1 Internal Architecture of a Microprocessor

2.1.1 Draw and interpret a block diagram showing the internal architecture of a representative 8-bit microprocessor.

2.1.2 State and explain the function of each of the principal internal registers of a representative 8-bit microprocessor.

2.1.3 State and explain the function of each of the principal external connections of a representative 8-bit microprocessor.

2.1.4 Explain the need for a clock and distinguish between external and internal microprocessor clocks.

2.1.5 State the range of typical clock frequencies and periodic times for common 8-bit microprocessors.

2.1.6 Use manufacturers' literature to determine the supply voltage, pin-out, and internal features of any common 8-bit microprocessor.

Microprocessors

In Part 1 we briefly mentioned that a microprocessor performs the functions of a central processing unit (CPU) within a microcomputer. We also stated that the microprocessor provides control and synchronization signals for the rest of the system. From this, it should be obvious that the microprocessor is the single most important component within any microcomputer system.

The basic internal elements of a microprocessor are as follows:

(a) registers for temporary storage of instructions, data, and addresses

(b) an arithmetic logic unit (ALU) able to perform a variety of arithmetic and logic functions

(c) control logic which accepts and generates external control and supervisory signals (such as RESET and READ/WRITE) and synchronizes data transfers within the system.

Registers

Internal registers can be thought of as arrangements of pigeon holes into which data (in binary form) can be placed during processing. Some registers are directly accessible to the programmer (i.e. he can set to read their contents at will) whilst others are reserved for the machine's own use. Registers may also be classified as "dedicated" (i.e. they have a specific purpose such as pointing to a memory location or holding the results of an ALU operation) whilst others are described as "general purpose".

In the case of an 8-bit microprocessor, most of the general purpose registers will be capable of storing eight bits. Furthermore, since each of the bits may be either 0 or 1, there will be a total of 256 possibilities for the contents of such a register, ranging from 00000000 to 11111111. Registers used for "pointing" to memory locations, on the other hand, will generally be capable of holding sixteen bits and consequently their contents may range from 0000000000000000 to 1111111111111111 (ie, 0 to 65535 decimal).

The data bus lines in an 8-bit microcomputer are labelled D0 to D7. The most significant data bit (i.e. that with the greatest binary weight) appears on D7 whilst the least significant bit (i.e. that with the least binary weight) appears on D0. In the case of a 16-bit address bus, the lines are labelled A0 to A15 and the most and least significant address bits are respectively those which appear on address lines A15 and A0. The most and least significant bits are often referred to as the MSB and LSB last (see Part 1).

Unfortunately, there is some considerable variation in both the internal architecture and terminology used by different microprocessors manufacturers. Despite this, there are a number of common themes. The major microprocessors families, for example, tend to retain a high degree of upward compatibility both in terms of internal architecture and the software "instruction set" and that is clearly an important consideration in making a new product attractive to the equipment manufacturer.

Introducing IMP

IMP stands for introductory microprocessor, a hypothetical device

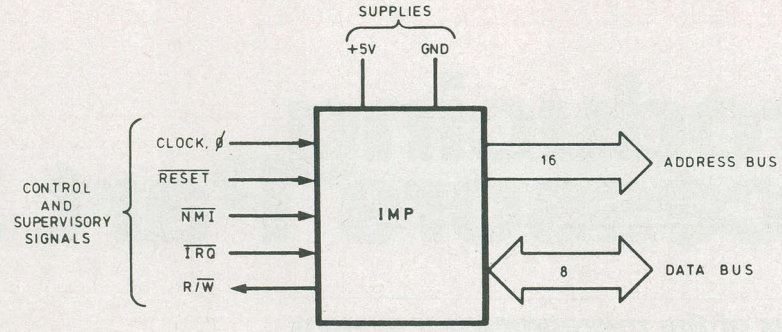


Fig. 2.1. IMP's external connections. Note that a bar over a particular signal indicates that it is active-low (logic 0 when activated).

which we shall be using to explain some of the fundamental concepts of microprocessors. We have chosen to follow this route, rather than tailor our description to real microprocessor, in order to keep the explanation as simple as possible. IMP contains many of the features found in a real 8-bit microprocessor without favouring the architecture of any particular processor family. By this means, we hope to provide readers with a gentle introduction to microprocessor avoiding superfluous or processor specific information which may otherwise serve only to confuse the newcomer.

Important differences between IMP and real microprocessors will be discussed as we progress but readers who require detailed information on particular microprocessors need not worry as we shall be presenting this information in the current series of Data Cards. These cards will feature all the most popular 8-bit microprocessors (6502, 6800, 8085 and Z80) and will build to provide a useful library of microprocessor related data.

IMP has an 8-bit data bus, 16-bit address bus and five control and supervisory signal lines. Like most 8-bit microprocessors, IMP has a 40-pin d.i.l. package and operates from a +5V supply. IMP's connections with the outside world are shown in simplified form in Fig. 2.1

Internal architecture

The internal arrangement (architecture) of the IMP is shown in Fig. 2.2. At first sight this diagram may look rather complex so we will spend some time explaining each individual feature and how it relates to the working of the unit as a whole.

The majority of IMP's internal registers are linked together by means of an internal data bus. This bus can be thought of as a highway along which bytes are transferred from one register to another. Since we are dealing with an 8-bit microprocessor, the internal data bus is naturally eight bits wide.

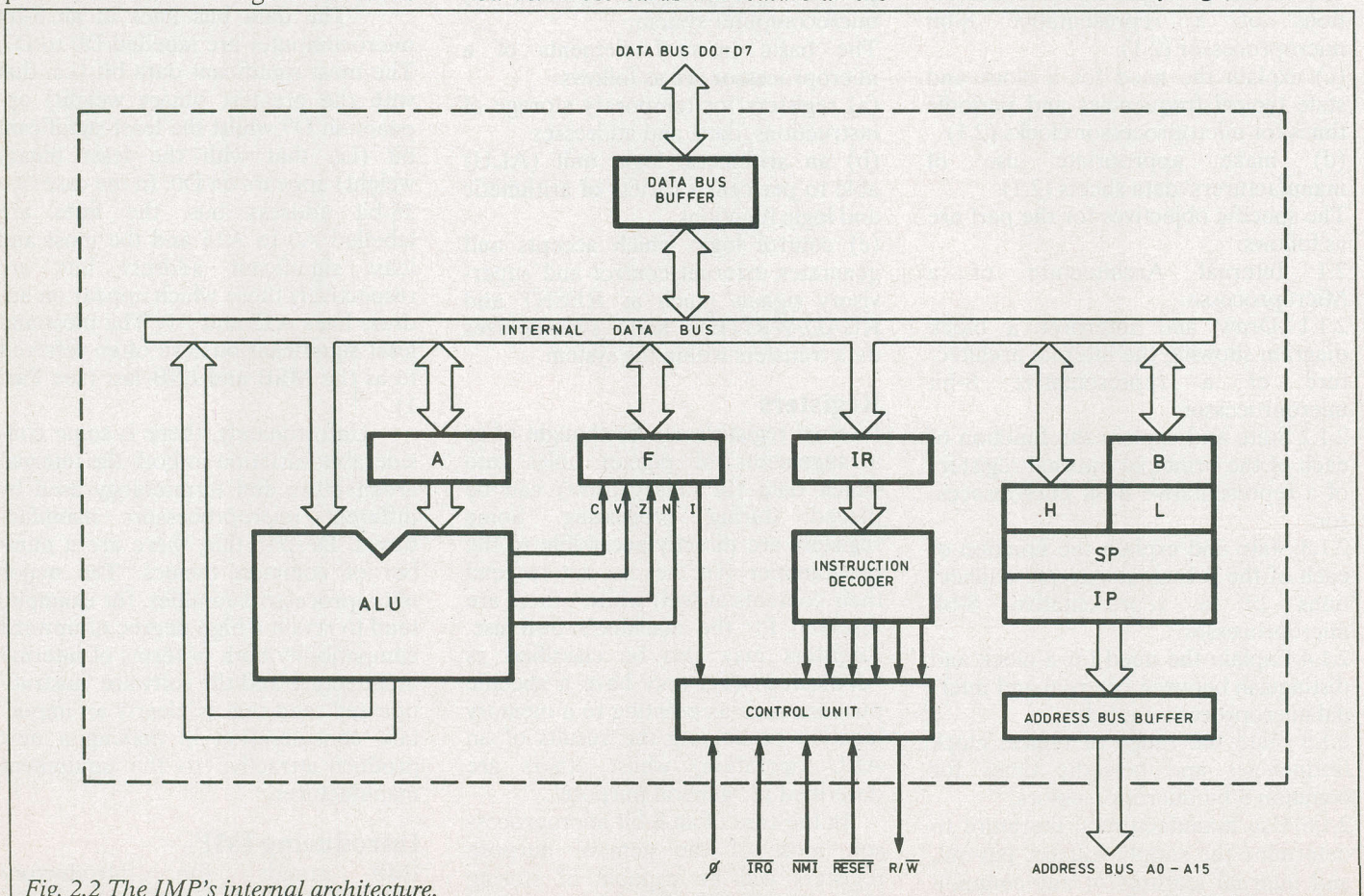


Fig. 2.2 The IMP's internal architecture.

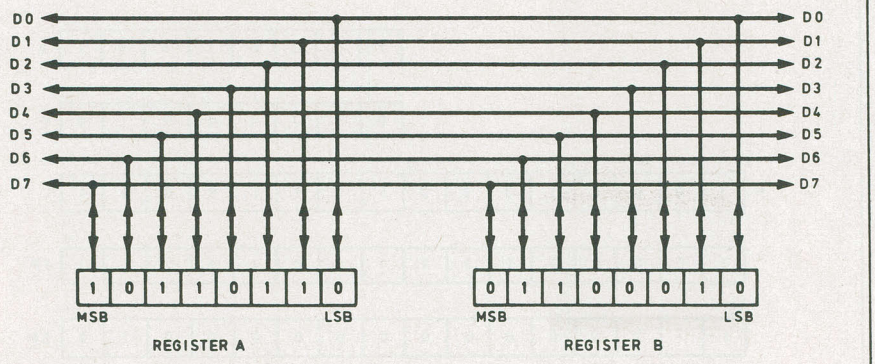


Fig. 2.3. Connections to the internal data bus.

Fig. 2.3 shows how two 8-bit registers (A and B) are coupled to the internal bus. Separate lines from the control unit (not shown on either Fig. 2.1. or Fig. 2.3) are used to determine whether:
(a) the contents of the register are to be made available on the bus (so that it may be copied elsewhere),
or (b) the data currently present on the bus is to be latched into the register (replacing whatever was there before),
or (c) the register is to be isolated from the bus (preserving its contents for future use).

Now, consider the process of copying data from register A to register B. We would need to make the data in register A available on the bus (case (a) above), latch the data into register B (case (b) above), and ensure that every other register connected to the bus was currently isolated (case (c) above). If this is beginning to sound rather complex, there is no need to worry as the generation of the necessary internal control signals is both implicit in a particular instruction and entirely automatic.

Data Bus Buffer

The data bus buffer separates the internal data bus from the external data bus and it incorporates eight individual bidirectional current amplifiers. The buffers may be made to receive data from the external bus or transmit data to the external bus in response to control signals (not shown in Fig. 2.2). The buffer helps regularize the logic levels received by the microprocessor and provides a reasonable amount of current gain for "driving" the external bus. The data bus buffer thus provides a means of isolating the microprocessor from the harsh world outside!
[Some microprocessors allow the microprocessor to isolate itself from the data bus by placing the data bus buffer in an open- circuit (i.e. disconnected) or "tri-state" condition. This allows other "intelligent" devices to place information on the data bus.]

Address bus buffer

The address bus buffer behaves in a similar fashion to that of the data bus buffer. It is, however, important to note that the individual address bus buffers are unidirectional since address information is only generated by the microprocessor and not received by it.
[Some microprocessors allow the microprocessor to isolate itself from the address bus by placing the address bus buffer in an open-circuit (i.e. disconnected) or "tri-state" condition. This allows other "intelligent" devices to place information on the address bus.]

Instruction Pointer (IP)

The instruction pointer is a 16-bit register which contains the address of the next instruction byte to be executed. The contents of the register is thus said to "point" to the next instruction byte. The contents of the instruction pointer is automatically incremented each time an instruction byte is fetched.
[Note: Many microprocessors refer to this register as a Program Counter (PC)]

Accumulator (A)

The accumulator is an 8-bit register which functions both as a source and destination register; not only is it the source of one of the data bytes required for an ALU operation but it is also the location in which the result of an ALU operation is placed.

Flag Register (F)

The flag register contains information on the internal status of the microprocessor and, in particular, signals the result of the last ALU operation. It is important to note that the flag register is not a register in the conventional sense; it is simply a collection of bistable latches which can be "set" or "reset" depending upon the result of an ALU operation. The output of each bistable can be considered to act as a "flag". IMP has the following

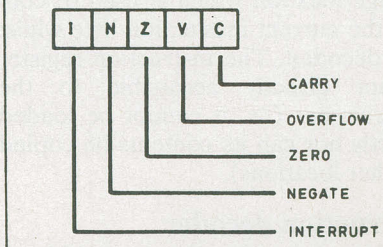


Fig. 2.4. IMP's flag register.

flags:
CARRY (C) – set to 1 when the last ALU operation has produced a carry
OVERFLOW (V) – set to 1 if the last ALU operation resulted in an overflow
ZERO (Z) – set to 1 if the result of the last ALU operation was zero
NEGATE (N) – set to .1 when subtraction has taken place, otherwise reset to 0
INTERRUPT (I) – set to 1 when interrupts are disabled (in this state the microprocessor is unable to accept and "interrupt request" generated by an external device).
The composition of IMP's flag register is shown in Fig. 2.4. It is important to note that once changed, the various flag bits remain either set or reset until a further change occurs. The programmer is only able to directly affect the state of the CARRY and INTERRUPT flags. The others change state indirectly as a result of program execution.

Stack Pointer (SP)

IMP needs to have access to an external area of read/write memory (RAM) which permits temporary storage of data. This area of memory is known as a "stack" and it may typically occupy

between 16 and 256 bytes of memory. (Note, however, that the stack is a dynamic structure and its size varies continuously during processing.)
The stack operates on a "last-in first-out" (LIFO) basis; data is "pushed" onto the stack and later "pulled" off it. The "stack pointer" keeps track of the extent of the stack by holding the address of the last used stack location.
[Note: Some popular microprocessors (e.g. 6809) have two independent stack pointers; a "system stack pointer" (SSP) and a "user stack pointer", (USP).)

Instruction register

The instruction register is a temporary storage location which is used to contain the current instruction byte whilst it is decoded. The instruction register is not directly accessible to the programmer (i.e. it cannot be loaded directly nor can its contents be copied to other locations).

Instruction decoder

The instruction decoder, a complex arrangement of logic gates with outputs which are fed to the control unit, operates on the instruction currently held in the instruction register. The instruction decoder informing the control unit of the actions demanded by the current instruction (e.g. the need to take the R/W line low and latch the contents of the HL register pair into the address bus buffer).

Control Unit

The control unit generates internal control signals (not shown in Fig. 2.2) which determine the direction, source and destination of internal data transfers, activates external control lines when required, and responds to external signals which arrive on the control bus. The control unit is also responsible for internal synchronization.

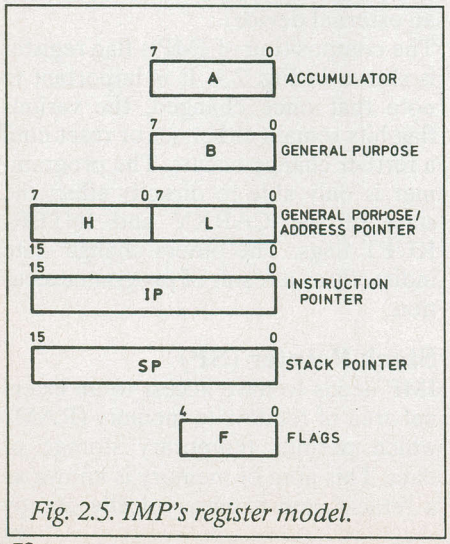


Fig. 2.5. IMP's register model.

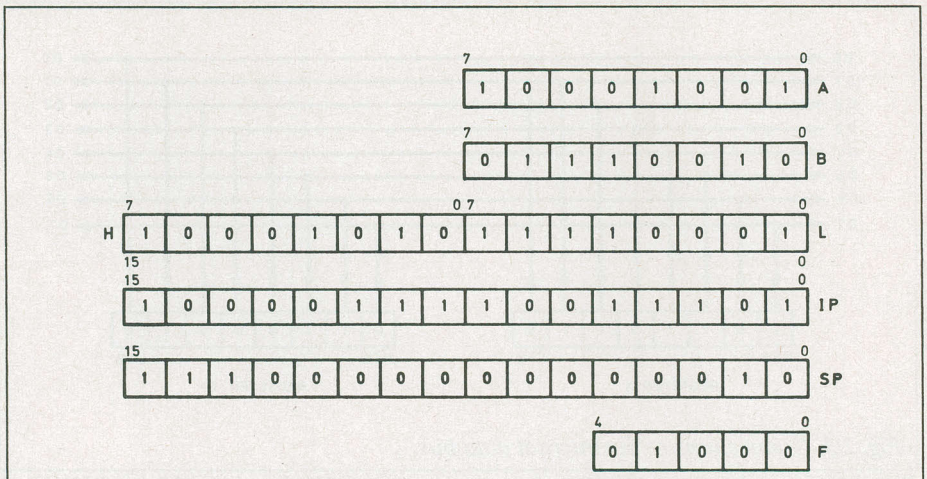


Fig. 2.6. The state of the registers for problem 2.1.

General purpose registers

Apart from the accumulator (A), IMP has three 8-bit registers which may be classed as "general purpose". These are B, H and L. Register B is often used as an "alternative accumulator", results which appear in the accumulator being regularly transferred to and from register B. The H and L registers can be used as individual 8-bit registers and may also be used "end- on" to provide a 16-bit general purpose register (referred to as the "HL register pair"). In this mode, HL can be used as a pointer to data stored in memory (i.e. the 16-bits in HL from an address at which data is to be stored or from which data is to be fetched). The HL register pair can thus be used as an "address pointer" and, in this context, the H register contains the "high" (most significant) byte of the address whilst the L register contains the "low" (least significant) byte of the address.

Register model

Whilst Fig. 2.2 provides us with some idea of IMP's internal arrangement, it is unnecessarily complex from the point of view of the programmer. The programmer is neither concerned with the links between registers nor need he/she be aware of internal features over which he/she has no direct control. In this context, the "register model" depicted in Fig. 2.5 provides a more useful representation of IMP and this merely shows the registers which are directly accessible to the programmer and over which the programmer has control.

Problem 2.1

Fig. 2.6 shows the state of IMP's internal registers at a particular point in the execution of a program. The MSB of each register (with the exception of the flag register) appears on the left and the layout follows that shown in the register model of Fig. 2.5.
(a) What is decimal value of the data in the accumulator?
(b) What is the hexadecimal value of the data in the accumulator?
(c) Which one of the three 8-bit general purpose registers has the GREATEST value?
(d) What hexadecimal address is pointed to by the Instruction Pointer?
(e) What decimal address is pointed to by the Stack Pointer?
(f) In which of the 8-bit registers is the MSB set?
(g) In which of the 8-bit registers is the LSB set?
(h) Which of the flags is set?
(i) Which of the flags is reset?
(j) If the HL register pair is currently being used as an address pointer, what hexadecimal address is it pointing to?
(k) Are-interrupts currently enabled or disabled?

Control Signals

IMP has five control bus signals. Four of these are inputs and one is an output. We shall briefly discuss the function of each:

Read/Write (R/W)

(output)
This line is taken low (i.e. to logic 0)

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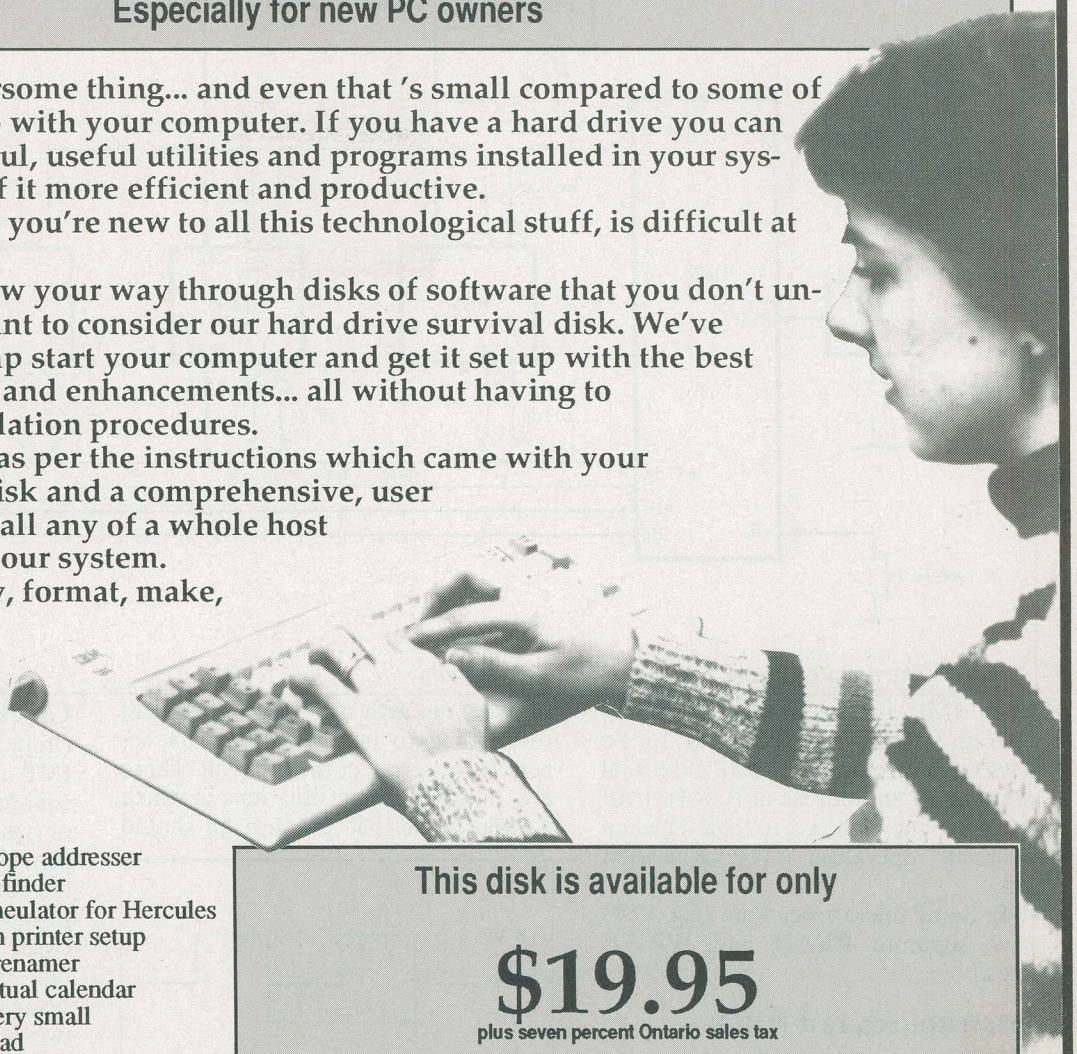
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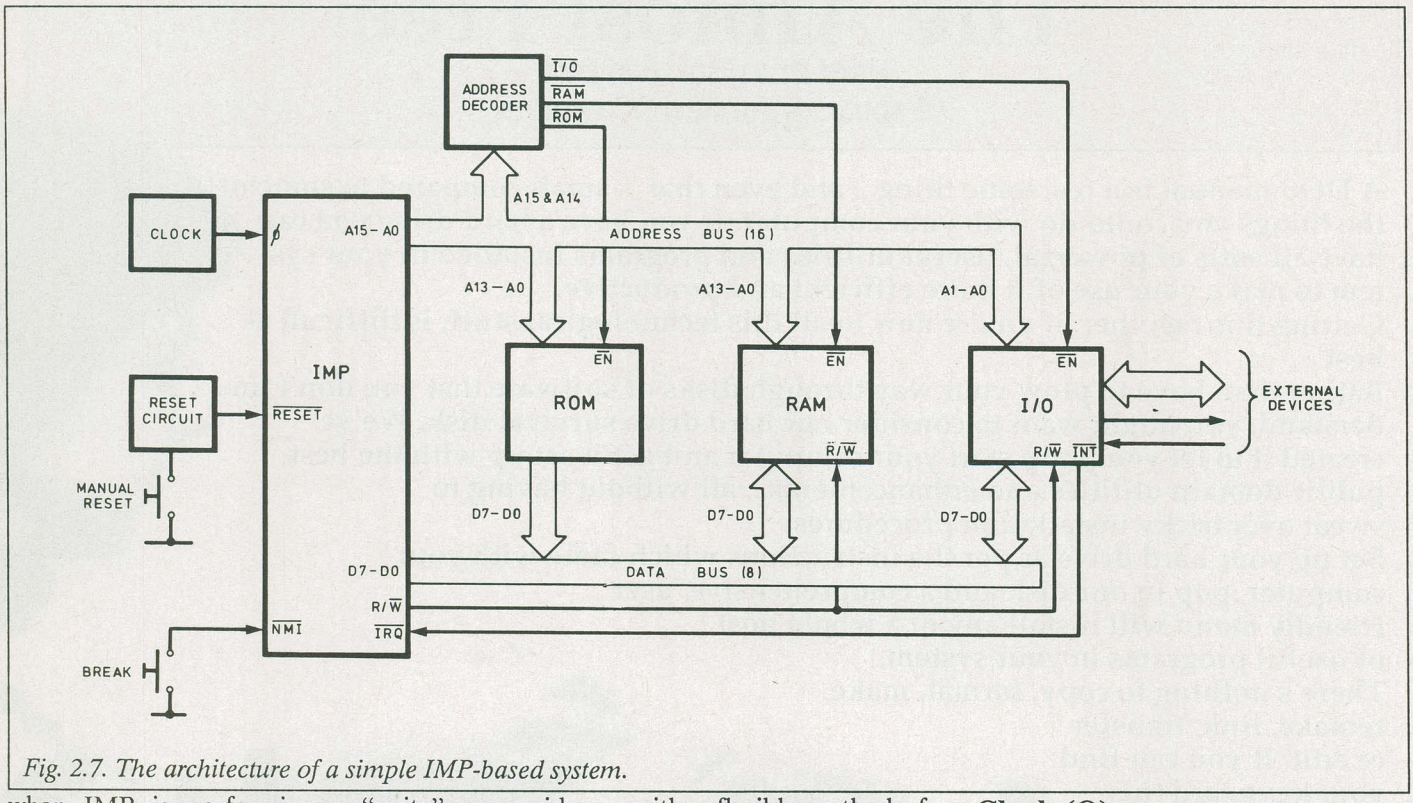


Fig. 2.7. The architecture of a simple IMP-based system.

when IMP is performing a "write" operation (e.g. when data is to be transferred from one of IMP's internal registers to an address in RAM). IMP takes the line high (i.e. to logic 1) when a "read" operation is being carried out.

[NB: Some microprocessors (e.g. Z80) have separate READ and WRITE lines.]

Interrupt request (IRQ)

(input)

This line serves as an input to the microprocessor and is taken low by an external device wishing to signal the fact that it requires attention. Provided the "interrupt flag" is reset (i.e. logic 0) this request will be honoured and the microprocessor will cease normal processing and execute the required "interrupt service routine". The interrupt line is said to be "active-low" (i.e. it is taken to logic 0 when asserted).

Non-maskable interrupt (NMI)

(input)

As we have seen, the response to an ordinary interrupt (IRQ) is determined by the interrupt status flag and thus the interrupt may be "masked". Instructions may be placed within the program which "set" or "reset" the interrupt flag hence disabling or enabling interrupts. This technique provides us with a flexible method of responding to interrupts; we can accept them or reject them at will. There are, however, some situations in which it is desirable that an interrupt should be serviced regardless of what else is going on. Hence a separate "non-maskable interrupt" line is provided. When this line is taken low, normal program execution is interrupted regardless of the state of the interrupt flag (i.e. regardless of whether interrupts are currently enabled or disabled).

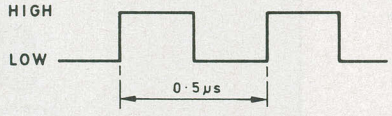


Fig. 2.8. Idealized 2MHz clock signal.

Reset (RESET)

(input)

This active low input to the microprocessor is used to initialize the system into a known state prior to normal execution of the program. When the RESET line is taken low, the program counter (PC) is placed in a defined state (by loading it with zero) and interrupts are disabled.

Clock (O)

(input)

IMP requires an accurate and stable square wave clock having a frequency of typically 2MHz. The clock is used to provide an accurate time reference for the control unit (see below).

[Many microprocessors have internal clock oscillators and merely require that a quartz crystal of appropriate resonant frequency be connected to two of the microprocessor's pins. The vast majority of 8-bit microprocessors operate with clock frequencies between 1MHz and 8MHz.]

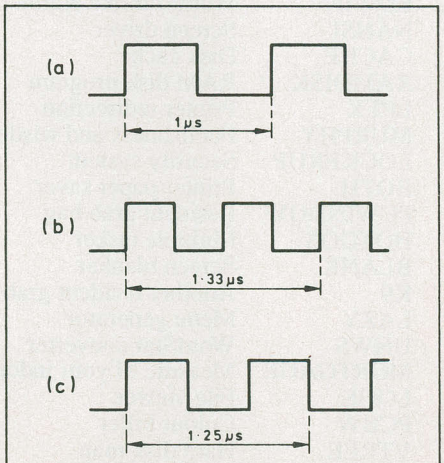


Fig. 2.9. Clock waveforms for problem 2.2.

Problem 2.3

The data sheet in Fig. 2.10 relates to the Intel 8080A microprocessor. Read the data sheet carefully (don't worry if you don't understand all of it) and answer the following questions:

(a) How many address lines are provided?

(b) How many addresses are available for input/output?

(c) What pin number is used for the RESET input?

(d) What pin number is used for the INTERRUPT input?

(e)How many clock inputs are required?

(f) Are the clock inputs TTL compatible?

(g) What supply voltages are required?

(h) Is the WRITE line "active-high", or "active-low"?

(i) What is the logical state of the WRITE line when a write operation is being carried out?

(j) From what address does execution commence when the RESET input is activated?

Fig. 2.10 Data sheet for Problem 2.3.

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The 8080A contains 6 8-bit general purpose working registers and an accumulator. The 6 general purpose registers may be addressed individually or in pairs providing both single and double precision operators. Arithmetic and logical instructions set or reset 4 testable flags. A fifth flag provides decimal arithmetic operation.

The 8080A has an external stack feature wherein any portion of memory may be used as a last in/first out stack to store/retrieve the contents of the accumulator, flags, program counter, and all of the 6 general purpose registers. The 16-bit stack pointer controls the addressing of this external stack. This stack gives the 8080A the ability to easily handle multiple level priority interrupts by rapidly storing and restoring processor status. It also provides almost unlimited subroutine nesting.

This microprocessor has been designed to simplify systems design. Separate 16-line address and 8-line bidirectional data busses are used to facilitate easy interface to memory and I/O. Signals to control the interface to memory and I/O are provided directly by the 8080A. Ultimate control of the address and data busses resides with the HOLD signal. It provides the ability to suspend processor operation and force the address and data busses into a high impedance state. This permits OR-tying these busses with other controlling devices for (DMA) direct memory access or multi-processor operation.

NOTE:
The 8080A is functionally and electrically compatible with the Intel® 8080.

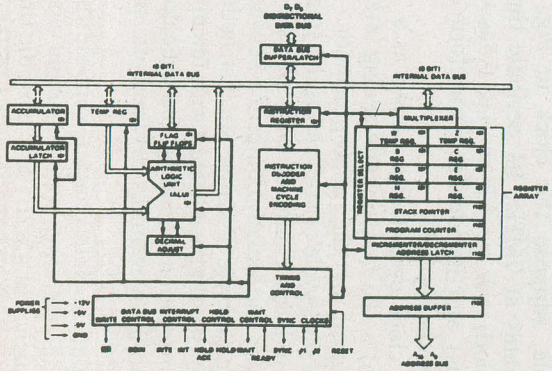


Figure 1. Block Diagram

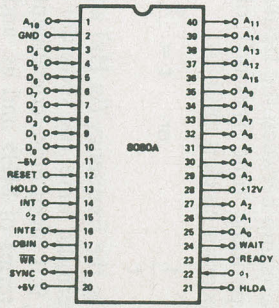


Figure 2. Pin Configuration

Table 1. Pin Description

Symbol	Type	Name and Function
A_{15}-A_0	O	**Address Bus:** The address bus provides the address to memory (up to 64K 8-bit words) or denotes the I/O device number for up to 256 input and 256 output devices. A_0 is the least significant address bit.
D_7-D_0	I/O	**Data Bus:** The data bus provides bi-directional communication between the CPU, memory, and I/O devices for instructions and data transfers. Also, during the first clock cycle of each machine cycle, the 8080A outputs a status word on the data bus that describes the current machine cycle. D_0 is the least significant bit.
SYNC	O	**Synchronizing Signal:** The SYNC pin provides a signal to indicate the beginning of each machine cycle.
DBIN	O	**Data Bus In:** The DBIN signal indicates to external circuits that the data bus is in the input mode. This signal should be used to enable the gating of data onto the 8080A data bus from memory or I/O.
READY	I	**Ready:** The READY signal indicates to the 8080A that valid memory or input data is available on the 8080A data bus. This signal is used to synchronize the CPU with slower memory or I/O devices. If after sending an address out the 8080A does not receive a READY input, the 8080A will enter a WAIT state for as long as the READY line is low. READY can also be used to single step the CPU.
WAIT	O	**Wait:** The WAIT signal acknowledges that the CPU is in a WAIT state.
$\overline{WR}$	O	**Write:** The $\overline{WR}$ signal is used for memory WRITE or I/O output control. The data on the data bus is stable while the $\overline{WR}$ signal is active low ($\overline{WR}$ = 0).
HOLD	I	**Hold:** The HOLD signal requests the CPU to enter the HOLD state. The HOLD state allows an external device to gain control of the 8080A address and data bus as soon as the 8080A has completed its use of these busses for the current machine cycle. It is recognized under the following conditions: • the CPU is in the HALT state. • the CPU is in the T2 or TW state and the READY signal is active. As a result of entering the HOLD state the CPU ADDRESS BUS (A_{15}-A_0) and DATA BUS (D_7-D_0) will be in their high impedance state. The CPU acknowledges its state with the HOLD ACKNOWLEDGE (HLDA) pin.
HLDA	O	**Hold Acknowledge:** The HLDA signal appears in response to the HOLD signal and indicates that the data and address bus will go to the high impedance state. The HLDA signal begins at: • T3 for READ memory or input. • The Clock Period following T3 for WRITE memory or OUTPUT operation. In either case, the HLDA signal appears after the rising edge of ϕ_2.
INTE	O	**Interrupt Enable:** Indicates the content of the internal interrupt enable flip/flop. This flip/flop may be set or reset by the Enable and Disable Interrupt instructions and inhibits interrupts from being accepted by the CPU when it is reset. It is automatically reset (disabling further interrupts) at time T1 of the instruction fetch cycle (M1) when an interrupt is accepted and is also reset by the RESET signal.
INT	I	**Interrupt Request:** The CPU recognizes an interrupt request on this line at the end of the current instruction or while halted. If the CPU is in the HOLD state or if the Interrupt Enable flip/flop is reset it will not honor the request.
RESET[1]	I	**Reset:** While the RESET signal is activated, the content of the program counter is cleared. After RESET, the program will start at location 0 in memory. The INTE and HLDA flip/flops are also reset. Note that the flags, accumulator, stack pointer, and registers are not cleared.
V_{SS}		**Ground:** Reference.
V_{DD}		**Power:** +12 ±5% Volts.
V_{CC}		**Power:** +5 ±5% Volts.
V_{BB}		**Power:** −5 ±5% Volts.
ϕ_1, ϕ_2		**Clock Phases:** 2 externally supplied clock phases. (non TTL compatible)

A complete IMP Microcomputer System

Fig. 2.7 shows the internal architecture of a complete microcomputer based on the IMP. Since this diagram is somewhat more complicated than that in Fig. 1 of Part 1, we shall attempt to justify the additional features which have appeared.

The reset circuitry is designed to take IMP's RESET input low for a short time (typically 20ms) when the power is first applied to the system or when the manual reset button is pressed. This ensures that the system initializes itself in an orderly fashion as IMP always commences program execution from address 0000H when its RESET input is taken low.

In order that data flow within the system is orderly and that there is no uncertainty as to whether the data present is valid or not, it is necessary to synchronize all data transfers using a reference clock signal. This signal, a symmetrical square wave, is generated by an external oscillator. For accuracy and stability, the clock is crystal controlled the functions at a fixed frequency of 2MHz.

The relationship between the frequency and periodic time (period) of a microprocessor clock is given by:

$$f = \frac{1}{t} \quad \text{or} \quad t = \frac{1}{f}$$

Where f is the frequency (in Hz) and t is the periodic time (in seconds). In practice, it is often more convenient to work in terms of MHz and us, and th same formula will apply. As an example, suppose the clock in Fig. 2 operates at 2MHz. Its periodic time (period) will be 1/2 us (i.e. 0.5us or 500ns) and its idealized waveform is shown in Fig. 2.8.

The clock cycle (often known as a T-state) is the fundamental timing interval used by the microprocessor. A "machine cycle" (M-cycle) is the smallest indivisible unit of microprocessor activity and usually comprises between three and five T-states. An instruction cycle (i.e. that associated with fetching an instruction, decoding and executing it) normally requires between one and five M-cycles.

To put this into context, suppose that IMP is operating at its maximum clock frequency of 4MHz. The periodic time of the clock (T-state) will be 250ns. A machine cycle (M-cycle) will then occupy from 0.7us to 1.25us whereas an instruction cycle will require some 1.25us to 6.25us depending upon its complexity. To put this another way, IMP is capable of executing between 160,000 and 800,000 instructions every second!

The two most significant address lines are fed to an address decoder which generates active low signals to enable the ROM, RAM and I/O devices (more of this in Part 5). At this stage it is merely necessary for readers to understand that ONLY one of these devices is enabled (i.e. linked to the data bus) at any particular time.

The all-important "break" key is connected to IMP's non- maskable interrupt (NMI) input. This allows the user to regain control WITHOUT having to reset the system (and erase the data and/or program currently present in RAM). The general topic of interrupts is outside the scope of *Introductory Microprocessors* and therefore readers need not at this stage concern themselves with the action which takes place when an interrupt is received.

Problem 2.2

What is the frequency of each of the microprocessor clock signals depicted in Fig. 2.9?

Glossary for Part Two

Accumulator
One or more registers associated with the ALU which temporarily store the results of ALU operations.

Arithmetic Logic Unit (ALU)
One of the essential elements of a CPU. The ALU performs various forms of addition, subtraction and logical operations.

Buffer
A hardware device which provides isolation between two parts of a circuit and which usually increases the drive capability of a signal. In the context of software, the word refers to a contiguous area of memory used for temporary storage of data when performing I/O.

Clock
The clock provides a reference timing source within a microcomputer system. The output of a clock comprises regular pulses of accurately defined frequency and period.

Flag
A bit contained within a flag (or status) register which indicates the internal status of the microprocessor or which signals the outcome of an ALU operation.

Instruction
A single command within a program. A complete sequence of instructions constitutes a program.

Interrupt
A signal generated by an external device which requires the services of the microprocessor or which needs to alert the microprocessor to a particular condition (such as imminent power failure).

Stack
The stack is a contiguous area of read/write memory that is accessed on a last-in first-out (LIFO) basis by the microprocessor and used for temporary storage of data and addresses.

Answers to Problems

2.1 (a) 137
(b) 89
(c) L
(d) 879D
(e) 57346
(f) A, H and L
(g) A and L
(h) N
(i) C, Z, V and I
(j) 8AF1
(k) enabled

2.2 (a) 1MHz
(b) 1.5MHz
(c) 1.2MHz

2.3 (a) 16
(b) 256 for input and 256 for output
(c) 12
(d) 14
(e) 2
(f) no
(g) +5V, +12V and -5V
(h) active-low
(i) 0
(j) 0(0000H)



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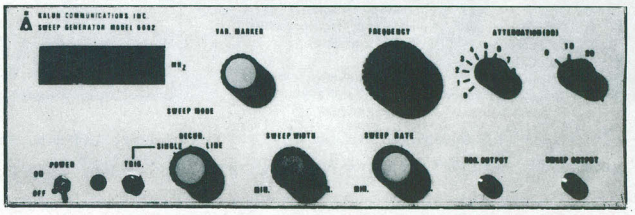
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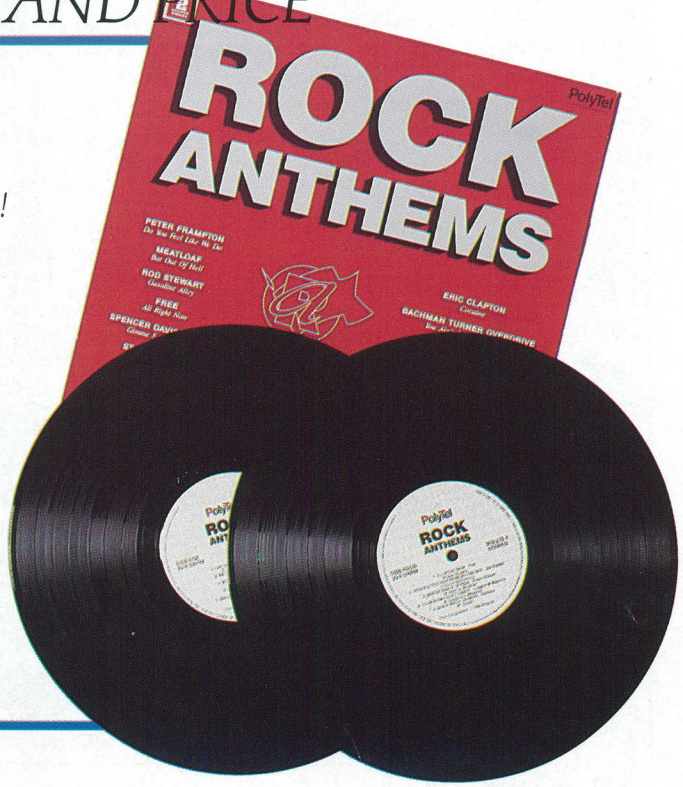
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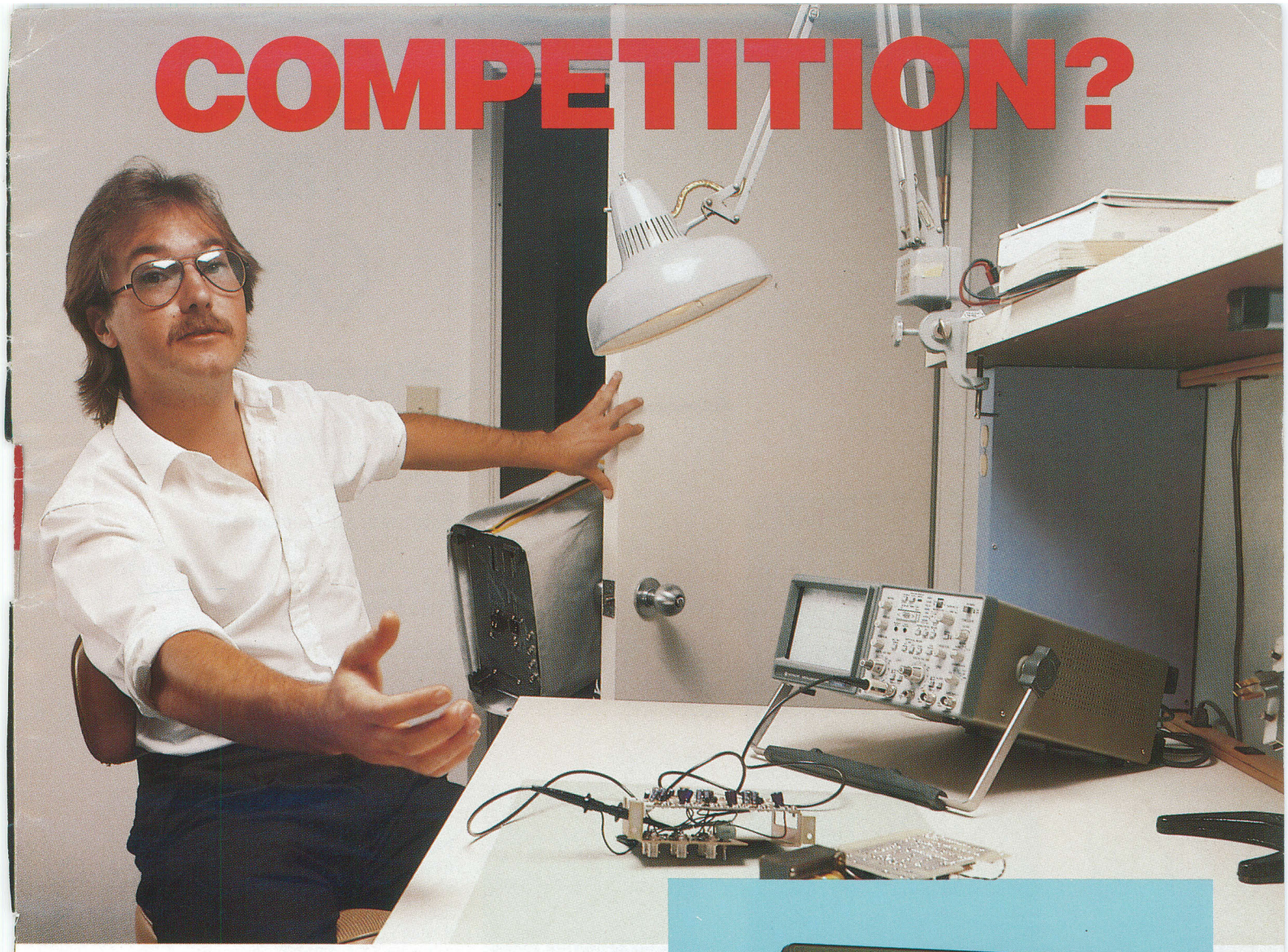
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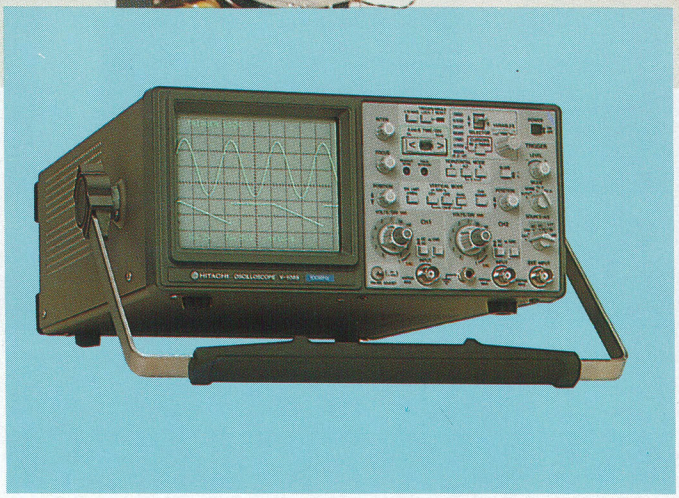
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